The Internet of Individuation

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This thesis is entirely the original work of Miranda Bruce.

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Dedication

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Abstract

This thesis engages in a sustained reconsideration of a new and evolving technology — the Internet of Things — along social scientific and philosophical lines. The Internet of Things (IoT) is a novel technical paradigm which connects 'things' in a way that allows them to collect and communicate sense data for analysis and action. IoT systems range from the everyday realm of smart home devices to government-backed agricultural management networks, massive industrial complexes spanning international supply chains and telecommunications networks themselves. The thesis does not seek to determine whether the Internet of Things' social effects are, or will be, progressive or regressive. Nor does it prescribe policy or other guidelines for its applications. Rather, the purpose of the thesis is to provide a critical engagement with the paradigmatic framing of the Internet of Things, to unpack the assumptions underpinning the practical accounts of its function, as well as the social scientific and popular evaluations that stem from these more common sense claims of the Internet of Things as a technological innovation. The thesis offers a more ontologically processual account of the Internet of Things, with an eye to grasping its participation in the ongoing production of novelty.

To this end, the main body of this thesis rethinks each of the IoT's basic technical operations: communication, sensing, and actuation. Each of these operations are transformed so that their technical realities are shown to be compatible with social scientific thought. Communication can be seen as modulation, sensing as concretization, and actuation as transduction. Three empirical chapters furnish these transformations with qualitative interviews with IoT practitioners in

Australia and abroad: student-run engineering labs in Canberra; the office of a smart building company bursting with dreams and tangles of wires; a watering system for a national Arboretum; a former IT consultant who runs a farm in Yass, NSW; and a smart city consulting agency in the UK that specializes in experimental and community-based IoT installations. These case studies are more than interesting instances of IoT systems; approached from a processual framework, they show how possible it is for social scientists to think about, write about, and interact with technical reality in more critical and productive ways.

This thesis thus contributes an original analysis of the Internet of Things using a process ontology framework. Specifically, it uses the work of Gilbert Simondon, Gilles Deleuze, and their contemporaries to repose the 'problem' of the Internet of Things as an open problematic. Although studies in the sociology of technology have considered the IoT in general, there is not yet an extended analysis of the IoT as a processual phenomenon in Australia or elsewhere. As such, this thesis provides additional insight into the Internet of Things as an object of sociological study and a specific phenomenon unfolding in Australia and overseas, and discusses what new methods of problematizing that the social sciences might adopt to engage with it.

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1 Introduction

1.1 Three machines

We have three machines.

First, lazily wending its way over the nooks and crannies of the ocean floor is The Internet. Thousands of kilometres of fibre optic cables, wound tightly together in bundles of stretched glass, surrounded by inches of metal and plastic, slowly unwound from giant spools on ships. Between some countries, the cables are heavy behemoth worms, terminating at large server farms straight into purpose-made ports, like comically large plugs into sockets. In other countries they show up randomly on beaches, thinly crawling up into one building or another. They transmit light. They make no noise.

Second, wifi — wireless fidelity — travels on radio waves. It travels around at its own specific frequency, seeking out devices which will agree to listen to its vibrations. When its advances are accepted, it is routed (quite literally) through a series of hands which peel off the clever wrapping around its packages of light. These gifts are arranged into something the device wants — what the device asked for — and then expressed through it like lights on a Christmas tree.

Third, sniffing around these quiet bright things is a collector. Inside weatherproof boxes, swaddled in insulation, amongst tangles of cords, sitting lonely on a post, fingers reach out through the ocean cables and vibrating lights. They can clutch the sensuous baubles of the real, opening their palms to say here it is. And these fingers, clasped tightly or loose, make claims on their treasures.

Between these three machines there is a concept. Concepts come from new relations; they are particular to the variables from which they arise. They emerge constantly, incessantly, out of the infinite problem of living. Our concept — the one which bubbles up from the ocean, into the radio waves, to be plucked by the curious fingers — is capable of encompassing the machines which connect the empirical, the abstract, and the living.

Today this concept is being held, with a velvet glove, by the Internet of Things.

The Internet of Things does three things: it senses the world; communicates that world to its community (its devices) and a community of others (its listeners);

and then actualises a goal which is pointed at that world. This goal is repeated until an arbitrary difference is registered — the world changes (or doesn't), the goal is restructured (or is deemed to fail), the community gets tired of listening (or there isn't enough to say). The whole process happens in the usual way of algorithmic democracy (which is to say, authoritarian at best and anarchic at average), and what we have afterwards is a strange, almost false, but very operational representation of whatever has just occurred.

Gifted with this concept, we can choose what to do with it. Usually, the choice is to turn this concept into a problem that can be solved. But already this turns the Internet of Things into a bad problem. Already it misunderstands our concept as a method of representing the real. But what if we were to turn the Internet of Things into a 'good problem', which is to say, a more productive one? This is the task of this thesis, which I undertake by creating and borrowing different concepts to rethink the Internet of Things at the level of its conceptual and technical operations.

1.2 Problems

> The IoT is here now, it is not the future but the present (Ashton, cited by van Kranenburg 2013, p. 1).

In 1999 Kevin Ashton, a radio frequency identification (RFID) researcher working for Proctor and Gamble, invented the term "Internet of Things" (IoT). He had coined the phrase for a company presentation as a way to make sense of the way that Proctor and Gamble were using RFID to maximise the value of their supply-chain network. He was adamant at the time that the Internet of Things was not presenting anything fundamentally new. Machine-to-machine technology had been used in factory settings for decades, as had rudimentary sensor networks, and their marriage with the Internet was an obvious step. He was trying to convince the company, Gillette, to track its warehouse items with RFID and GPS — a practice that is now commonplace in major distribution centres like Amazon.

In 2009, Ashton reflected on his role in naming the Internet of Things. Regardless of the sizable and sundry discourse the term had generated since 1999, he re- emphasised that the IoT is about solving a single problem:

> Today, computers — and therefore the Internet — are almost wholly dependent on human beings for information. Nearly all of the roughly 50 petabytes (a petabyte is roughly 1,024 terabytes) of data available on the Internet were first captured and created by human beings — by typing, pressing a record button, taking a digital picture or scanning a barcode.

> …Conventional diagrams of the Internet include servers and routers and so on, but they leave out the most numerous and important routers of all: people. The problem is, people have limited time, attention and accuracy — all of which means that they are not good at capturing data about things in the real world (Ashton 2009).

For Ashton, this dependence of Internet systems on humans is a 'big deal', a problem that imposes significant limitations on future opportunities for the technological empowerment of humankind. Unsurprisingly, Ashton's solution to the problem does not lie in limiting, but in enabling, technological innovation, with the hope that greater autonomy for technological systems will ultimately amount to greater freedom for human beings. In this, making the Internet more au fait with things is seen as a crucial step. Ashton (2009) writes:

> We're physical, and so is our environment. Our economy, society and survival aren't based on ideas or information—they're based on things. You can't eat bits, burn them to stay warm or put them in your gas tank. Ideas and information are important, but things matter much more. Yet today's information technology is so dependent on data originated by people that our computers know more about ideas than things…

In somewhat utopian tones, Ashton (2009) concludes that the future for the technological empowerment of human beings rests on the thing-empowerment of technology:

> We need to empower computers with their own means of gathering information, so they can see, hear, and smell the world for themselves, in all its random glory. RFID and sensor technology enable computers to observe, identify and understand the world — without the limitations of human-entered data.

Ashton's enthusiasm for a technological innovation that has since become commonplace appears dated, in part because the years since 2009 have changed the world to which the IoT responds and in which it intervenes. Most notably, the problem that Ashton identified as a lack is now a problem of excess:

> there is now a veritable deluge of non-human generated information. This includes sensor networks, machine learning, AI and all the sub-disciplines and technologies that accompany the mass non-human information network.

In losing something of its status as a technical novelty, the technologies that early discourse on the IoT named nonetheless remain at the centre of debates on the future of human-technological relations. Today, the IoT has characteristically become a problem for a knowledge economy bent on reintegrating human and non-human forms of intelligence toward an ethically and politically sustainable future, as the embedding of technologically oriented research programs and institutes into universities indicates (Waddell 2017).

Exemplary in this respect is the 3Ai Institute, which was officially opened in 2017 at the Australian National University, where this thesis was written. 3Ai is an interdisciplinary research program, which takes the critical problem of artificial intelligence and treats it as an interwoven issue involving computer science, engineering, philosophy, political science and sociology. An early version of their website opened with the following:

> 3Ai was created to enable the safe, ethical and effective design, integration, management and regulation of cyber-physical systems.So that as technology advances, humanity advances with it.
>
> Join us in keeping the humanity in technology (3Ai 2020).

In a nod to William Gibson, the page went on to proclaim that “(t)he future isn’t coming. It’s already here. Together, we’ll make sure it’s a good one” (3Ai 2020a). The institute’s website has since been rewritten to emphasise that their key research interest is in cyber physical systems (CPS): “(t)he intent is to shape a field of inquiry into CPS that is deeply and intrinsically connected to building the world we want to see: safe, sustainable and responsible” (3Ai 2020b). CPS is a generic term that encompasses the Internet of Things, and shares many of the core concerns identified by Ashton (2009), especially the question of how to make technology access increasingly disparate ‘things’. In 3Ai’s vision, this question cannot be answered without a morally and technically sound epistemology: “building a new intellectual approach is critical — and a large part of finding the answers we seek is by ensuring we’re asking the right questions” (3Ai 2020a). More than twenty years apart, Ashton, the 3Ai Institute, and a multitude of commentators since, frame technology as a problem of capturing the real world so that it may be acted upon. Capturing with an eye to action. The problems of capture and action are inextricably linked, via an ideal framing of the human-technical relation. In 3Ai’s case, the capture of the real will ideally be ‘safe, sustainable and responsible’, which is to say ethically sustainable (3Ai 2020a).

By framing the IoT (and its CPS cognates) as tools that can capture and instrumentalize the present, such technologies are figured as means to illuminate what is possible in the present, so that it may be put towards the best possible future. Predictably, competition over the future and its management is fierce. This is evident in the frays between tech giants such as Google, with its dominion over web standards, and Facebook, with its claims on worldwide algorithmic patterns, along with Tesla, with its investment in Mars colonization, the fight for space in everyday human machinations (advertisements) and events of global significance (USA elections). The battle to manage that future in the interests of social justice or human rights has given rise to a different set of debates, largely at the level of rhetoric about alternative digital futures. It is along these lines that Lizzie O'Shea's (2019a) Future Histories positions technological, and specifically digital, intervention into the production of alternate futures:

> We need to reclaim the present as a cause of a different future, using history as our guide. By stitching historical ideas and moments together and applying them to contemporary problems, it is possible to create a usable past, an agenda for an alternative digital future (O'Shea 2019a, p.9).

For O'Shea, the immediate problems posed by the Internet of Things — mass surveillance, the erosion of consumer rights, algorithmic bias — have effectively always been ingrained into tech company practices and encouraged by governments and corporations alike. Our way out, she argues, is to "foster a culture that celebrates technology for peaceful purposes and challenges its prevalence in industries of violence and oppression, such as prisons, policing and the military" (O'Shea 2019b). Her concern is that without such a culture, the

IoT will follow the same trajectory as the 1970s Ford Pinto, a car that continued to be manufactured despite its propensity to burst into flames (O'Shea 2019). Needless to say, the way in which the Internet of Things is conceived is of crucial significance to the futures imagined in its name. The vision associated with a network-oriented understanding of the IoT will be significantly different from that associated with an object-oriented paradigm (Atzori et al 2010, p. 2), while those who identify its technological novelty with the communication between virtual and physical worlds (Miorandi et al 2012) will have yet another 'IoT vision' for the future.

Eking out the implications of the Internet of Things is a core concern for this thesis, though my interest is not merely a critical one. That is to say, while I do not wish to contribute to celebrations of the Internet of Things as the bearer of a more potentialized future, I am equally loath to diagnose the IoT as the site for the reinscription of familiar relations of power. According to Bunz and Miekle (2018, p. 22), for instance, "social, economic and political interests … select, research, invest in and promote certain technical possibilities over others to decide which of the many possible internets of things will become realized." Yet such unveilings of interests ultimately reduce the engagement with the Internet of Things into what we might call the 'who question.' Whose interests do new technologies reflect? Who is allowed to speak about and on behalf of a technical system? How are the outputs of a technology acted upon, and who is allowed to act on them? Who is excluded from the futures to which such innovations give rise?

Such questions are disturbing in part because of their familiarity. They do little to grasp any real novelty in the Internet of Things, evidenced by the fact that they are readily answered in recognisable terms. Institutions celebrated for their cutting-edge perspectives tackle the task of critical engagement with an armoury of familiar concepts. For the 3Ai Institute, for instance, it is necessary to evaluate technological innovations by orienting ourselves to key concepts and big questions: Agency ("How much agency do we give technology?"), Autonomy ("How do we design for an autonomous world?"), Assurance ("How do we preserve our safety and values?"), Indicators ("How do we measure performance and success?"), Interfaces ("How will technologies, systems and humans work together?"), and Intent ("Why has the system been constructed? By whom? And for what purposes?") (3Ai 2020a). Such concepts aim to develop a politics of possible technological futures, with strong scientific legitimacy to support that politics. The realisation of such futures is posed as a certainty, the only indeterminate element being the pace of their realisation. Thus the bounds of the problem and the margins of freedom come to rest on practical technological questions of human responsibility, planning, engineering and ethics. Producing the framework through which such a practical technological philosophy can operate becomes a celebrated bipartisan political effort, now widely funded in Australia and many other economically developed countries (Rainie & Anderson 2017; European Commission 2021; NIST 2021).

Research initiatives such as the 3Ai Institute generate significant discourse, critical intervention, and of course, money, in academic sectors which otherwise might be pushed into the role of armchair punditry. Yet such initiatives are profoundly limited by the social theoretical terms in which they are framed. To the extent that they remain at the level of pragmatic techno-philosophy ventures oriented to the use of the innovation, discourses on the IoT are characteristically polarised into utopian or dystopian diagnoses. According to Fred Turner (2006), the polar divide between the utopian visions of digital liberalism, on the one hand, and dystopian warnings about the control and conformity enabled by digital technologies, on the other, echo the polar division of the American popular imagination of the 1960s vis a vis computerisation. In any event, what is notable is the manner in which, over time, the notion that technological futures must be either good or bad becomes naturalised as the only way to address their implications.

Here I am addressing those academic approaches that rely on the separation of the social, technical and natural, in order to analyse the impact of technology, whether that separation is encouraged or bemoaned as an ontological necessity. The division between the social and the natural, for example, has been deeply interrogated, though I would suggest that this has often been at the expense of a deeper engagement with the technical. Donna Haraway (1990) inaugurated one of the first extensive critical engagements with the intersection between the social, technical and natural in her *Manifesto for Cyborgs*. Haraway (1990, p. 196) proposed the cyborg as a remedy to the deepening binaries she observed in the progressive feminist and socialist engagements with technology at the time, which emphasised the “imagined organic body” as the key to resisting the “necessary domination of technics”. She examined the manner in which life came to be captured by the tools of technoscience and ultimately instrumentalized through what she called the informatics of domination: “the translation of the world into a problem of coding, a search for a common language in which all resistance to instrumental control disappears and all heterogeneity can be submitted to disassembly, reassembly, investment and exchange” (Haraway 1990, p. 206). Under this form of domination, “(t)he entire universe of objects that can be known scientifically must be formulated as problems for communications engineering (for the managers) and theories of the text (for those who would resist)” (Haraway 1990, p. 204). Haraway points here to a critical weakness in available approaches to the informatics of domination; namely, that the technologies of domination present themselves as fundamentally linguistic phenomena. While this opens up a universe of experimentation and resistance within coding and discursive practices, it cordons off real technical operations to the domain of communication and, ultimately, the instrumentalism of “problems”. Haraway describes the material reality of this breed of technoscience — the “microelectronics”, “satellite systems”, “medical constructions”, “high tech military establishment[s]”, “video games and highly miniaturized television” — as “mundane, largely economic realities” (Haraway 1990, pp. 207-208). Yet, she also notes that such realities form the basis of the new divisions of labour that uphold the informatics of domination, as much as they enable biological bodies to “become biotic systems, communication devices like others” and thereby enter the cyborgian circuit of ontological partiality (Haraway 1990, p. 220).

In the *Manifesto* and more recent works, Haraway joins those proponents of (feminist) science and technology studies (STS) who insist on examining the ontological and epistemological implications of technologies that render indistinct the social, natural and technological domains. One of the more enduring achievements of such work has been to challenge the dichotomies that have defined and prescribed human experience and human/non-human relations. Concepts such as the cyborg (Haraway 1990), the network (Latour 2005), the spime (Sterling 2005) and the hyperobject (Morton 2013) have offered new ways of thinking about the entanglement of technology with human and non-human realities and the kinds of partial knowledge that such entanglements require.

While I recognize the contribution of such scholars, I am less interested in situating a technology such as the Internet of Things in the practices through which its development and applications unfold, or in inventing concepts through which to bring its potentials to fruition, than I am in exploring the precise technical reality of the IoT's operations. Similarly, in gesturing toward the potentials of the technological developments designated by the now somewhat tired moniker, the "Internet of Things," the potentials that are immanent to its technical operations, in a virtual if not entirely actual sense, are what concern me. My point is not that technical reality is entirely distinct from social reality. Rather, it is that the kinds of questions that Haraway was asking about the hybrid potentials of human-technological reality are to some extent out of date, not least because technology is decidedly more constitutive of social reality than it was twenty odd years ago. My point, then, is that technical reality demands to be understood on its own terms.

Ultimately, my wager is that the Internet of Things offers more than simply a new set of social, moral and technological problems to solve. It also offers an opportunity to rethink the way in which technologies create problematics of thinking. In exploring what it would mean for the social sciences to be adequate to the task of thinking with the Internet of Things, I do not mean to imply that the social sciences are inadequate and must go out of their way to make up for their lack. In quantitative terms, a lack of discourse about technology is certainly not the issue. There are endless tools for managing technological change, calls for new policies, research programs, and government funded studies to generate reliable and meaningful answers to similar questions: "Is this device good for us? How will new technological infrastructures bring about a better society?". It is a self-feeding machine of questions and answers, with each new technology demanding new questions and solutions. The issue is the manner in which we are able to conceptualise technological novelty, beyond the questions habitually asked of its significance for us. In finding new ways to *think* new technologies, and the IoT in particular, I will be resisting a few dominant modes of critique, which I will detail in Chapter 2; briefly, these modes of critique fall into either utopian/dystopian rhetoric or discourses concerned primarily with instrumentalization. Firstly, utopian and dystopian frameworks presume a set of problems that are either exacerbated or solved by a given technology. By positioning the IoT within a problem/solution framework, wherein the social problems of the present are either ameliorated or exacerbated by new technologies, what technology *is* and *does* is often, if not always, bypassed. In a similar vein, the discourse of instrumentalism produces the Internet of Things as a problem in the merely negative sense, and the demand for a solution appears to naturally follow. Rather than follow this line of critique and recount the ways that the IoT is replicated in new social forms, I want to pursue an analysis of the Internet of Things on the basis of its engagement with, and production of, unfolding and emergent realities.

What, then, is the nature of this engagement with the world? What claims does the Internet of Things make upon both reality and potentiality? Turning to technical accounts of the IoT's general capacities sheds some initial, and fairly straightforward, guidance:

> Sensor devices gather information from the physical environment or a monitored system (e.g., temperature, pressure, vibrations), optionally perform a preliminary local processing of acquired information, and send (raw or processed) data to a controller. Based on the received information, the controller performs appropriate actions, through actuator devices, to change the behaviour of the physical environment or the monitored system. (De Guglielmo, Anastasi & Seghetti 2014)

This fairly typical account, published by an international engineering body and intended for that audience, reads equally like a set of instructions as a generalised description. Of course, with the expansion of the IoT into public consciousness, descriptions of the IoT and its purpose can now vary widely, from "an emerging architecture" meant for "exchanging goods and services" (Weber & Weber 2010), to an "intelligent environment" for human services (Chin, Callaghan & Allouch 2019), to a "market … heavily driven by specific use case scenarios" (Boston Consulting Group 2017). In these accounts, the IoT is at times attributed with a godlike capacity to bring all manner of "things" into connection, and to instrumentalize those "things" in any desired configuration. These capacities are perhaps not immediately apparent in the technical description above, though they do connect to its *general* ability to act on a set of data according to both the sensate reality of a given environment, and according to what has already been deemed “appropriate”. My contention is that these two accounts, the technically generalised and the politically specific, are not entirely dissimilar; they both rely on a *mode of thought* (about the IoT specifically, and perhaps technology in general) that is concerned with distinguishing and instrumentalizing the IoT’s particular *claim* upon reality.

With an eye to pursuing this argument throughout the thesis, I suggest that it is useful at this point to present the specific reality of the Internet of Things in a formula, which, while it certainly does not exhaust the descriptions that could be made of the Internet of Things, does give a sense of the claim that it makes upon contemporary reality. The formula, which will guide the enquiries into the Internet of Things pursued throughout the thesis, is the following:

> The Internet of Things claims to record life in such a way that can be acted upon.

The point of articulating such a formula is to express the mode of operation that has thus far characterised engagements with IoT systems as technical objects, which have a stake in, or claim upon, reality.

To be clear, it is not simply claims *about* the Internet of Things that interest me. To take as a starting point the discursive claims that humans make about technical reality is to presume the discretion of the speaking human subject and the technical object. It is to remain at the level of discrete individuals and thus to fail to account for the genetic capacity of the Internet of Things. It is, then, to miss much of what is going on: the co-existence and co-emergence of technical and human mentalities, for instance.

Further, in saying that the IoT 'claims', it is not my intention to personify it. It is not a question of attributing a human-like agency to the Internet of Things. Rather, what I am pursuing here is an enquiry into the manner in which the Internet of Things has thus far been conceived, with an eye to gaining a more adequate sense of its actuality and its potential. To the extent that the Internet of Things is approached through a representational perspective, the claim of the Internet of Things will habitually be reduced to its ability to realise a pre-existing possibility. According to this common sense perspective, what an IoT system does is to capture the characteristics of a given environment, by distinguishing those characteristics that have actually arisen (and are therefore fully real) from those that could have potentially arisen (but remained in the realm of the un-real). In such narrow conceptions, the question of the real is settled almost at the very moment it is raised; claims arise only as long as it takes to distinguish the false claimant (the merely possible) from the true (the real).

In challenging the application of this common sense, representational framework to the Internet of Things, my aim is to rescue our understanding of its technical reality from the hold of a thought that *reduces it to that which is* *given*, and thus *fails to grasp its ontogenetic capacity*. I will develop this idea extensively throughout the thesis. For the moment, we should note that the very idea of the claim is, in complex ways, entwined with that history of thought that reduces thinking to an act of recognition (Deleuze 1994). As Gilles Deleuze (1994) has famously argued, along with several non-representational and affect theorists in his wake, the "dogmatic" image of thought regards thinking as an act of recognising that which is given to it. And what is required for such thought is a kind of agonism, as in the dialectic method of testing thought by distinguishing true and false claimants to reality. Here, individual claimants in the realm of knowledge possess degrees of proximity and distance to the Idea to which a claim is laid; a thing is more or less Good, more or less Just (Deleuze 1990). Individuals, then, are rivals to the truth and things, in opposition to ideas, "are always something other than what they are: at best, they are only second-hand possessors, mere claimants or 'pretenders' to the Idea itself. They only lay claim to the qualit[ies of the Idea], and can do so only to the degree that they participate in the pure Idea" (Smith 2006, p. 96). This method of judgement, which has its foundations in Platonic representation, requires a way to sift through rivals, to "distinguish the authentic and the inauthentic, the good and the bad, the pure and the impure, from within an indefinite mixture or multiplicity", like "the search for gold" (Smith 2006, p. 94). Discerning the difference between claimants, and thus moving closer to truth, is a matter of discerning what has already self-selected; the difference which needs to be discerned "lies entirely within the depths of the immediate, where the selection is made without mediation" (Smith 2006, p. 94).

In any case, it is not too difficult to see this relationship between truth and claimants in the current political climate. From established forms of judgement in the judicial system to peer review and public policy auditing, this method of distinguishing rival claims is fundamental. Yet, classical bastions of settling rival claims — supreme courts, select media outlets, the scientific community — are today facing epistemological and ontological threats, from so-called fake news to the populist rejection of scientific findings. In the face of this challenge to established methods of distinguishing true and false claimants, novel technological ensembles appear to pose a solution. They are increasingly credited with a capacity for reliable judgement of the quality of participation in a given Idea, as when AI is used to determine the bias of court judges relative to ideas of justice, equality or fairness, or ideas of injustice, such as racism or ableism (see Conitzer et al 2017).

At stake here is the potential for the Internet of Things to be judged according to its participation in a given idea; to what extent can the smart city, for instance, lay claim to participate in the idea of democracy? Beyond this, the Internet of Things might function as a way of judging the participation of things in a given idea. For instance, a politician could conceivably use an IoT system to determine which neighbourhoods in their electorate (or suburbs in their state, or states in their country) are participating most genuinely in a version of "the good life". Levels of air pollution, weighed against instances of respiratory illness, could be used to indicate the balance between industry and health. The movement of bodies towards polling places on voting day could indicate citizens' participation in democracy. What is notable is that, faced with the myriad ways in which technologies are producing difference in the world, the social sciences have more often than not sought to make sense of such difference by subordinating the technical ensemble to an idea of the good life, to which practices of surveillance, the processes of capitalism, or the ideologies of neoliberalism appear to pose a threat (Howard 2015; Coletta & Kitchin 2017; Birch 2020). Framed in accordance with these representational presumptions about the nature of reality and the role of the claim as arbiter, technology is positioned as an increasingly able judge of the difference between claimants, according to the degree of resemblance between claimant and idea. Equally, technology's contribution to the solution of a social problem is increasingly judged on its ability to perform the work of judging resemblance; in other words, to be a successful claimant to Judgement itself.

If the Internet of Things has any part in rendering the world thinkable, it does so by making it communicable, sensible and able to be acted upon, technologically capturing and making a claim upon — which is to say, producing — the real. In this respect we can recall Isabelle Stengers' (2003) argument that the paradigm of scientific experimentation brings things into being which would otherwise exceed our capacity for observation. Stengers extends her argument into the compelling claim that the activity of scientific experimentation produces "the power to confer on things the power of conferring on the experimenter the power to speak in their name" (Stengers 2003, p. 31). This problematization of scientific activity, power and knowledge speaks to the politics of "the event of experimental invention" (Stengers 2010), and to the network of collegial assent and dissent which produces the drama of rebuttal "to test the reliability of the witness [that the scientist] claims to have produced" (Stengers 2010). While Stengers analyses this process of collegial scientific drama excellently, too much focus on that drama can obfuscate the way that the claim is operating on the level of the machine or technical object. It can focus too much on the already-individuated terms of the scientist, the colleague, the hypothesis, and so on, and mistake "the claim" as only a statement rather than an undecided question.

To return to the formula provided above — the Internet of Things claims to record life in such a way that can be acted upon — we should note that this is presented as a partial statement, intended to lead the reader away from conceiving of the Internet of Things in crudely representational terms. Rather than reducing its technological and social novelty to its ability to judge novelty against the given, the centrality I am affording its claim is intended to provoke, by figuring the Internet of Things as a pressing *question* regarding reality and its potentials. The main inspiration for this approach is Deleuze's endeavour to overturn Platonism, and his argument that true thinking is forced by an encounter with that which lies outside established categories of recognition (Deleuze 2004). With this in mind, I will argue throughout this thesis that adequately *thinking* the claim-making powers of the IoT requires an encounter with the provocation provided by its *technical reality*.

In this respect, it is to the philosophy of Gilbert Simondon that I turn, with an eye to extending Deleuze's own interest in his philosophy of individuation more directly toward the question of technical reality and specifically that of the

Internet of Things. Simondon is increasingly recognised for his unique approach to technical-human relations as one concerned primarily with ontology and interoperability. Crucially, Simondon challenged the schemas of thought that pose material potential as entirely undetermined and unformed, awaiting an ideal form to impress upon and transform it from passive matter into meaningful activity. Elizabeth Grosz's (2012, p. 37) endorsement of Simondon as a philosopher capable of "providing models for understanding how things, including living beings, are brought into existence as cohesive individuals" is instructive in this respect. Grosz (2012, pp. 54-55) extols Simondon's ability to "question the assumptions that structure thought at a particular moment in time" and while she recognises his contribution to "new ways of understanding identity, transformation and creation" she rightly insists that the focus on individuation poses a challenge to an ontology of identity. The following chapters will explore this notion of individuation more thoroughly, but suffice to say for now that individuation is a crucial concept for rethinking the Internet of Things in a way that integrates the technical, the psycho-social and the collective into a problematic worthy of its transformations.

Primary among Simondon's philosophical reconceptualizations is his redefinition of problems as ongoing experiments. Deleuze and Guattari (1991) famously integrated Simondon's reworking of "the problem" into their own project of transforming philosophy into a series of open problems that liberate thought. Striphas (2010) elaborates on their work together on modern philosophy:

> We know from *What Is Philosophy?* that communication is the enemy of

> creation. Could it be, then, that communication assumes this role by forestalling the passing of the present — by rendering the present *present*, as it were? In other words, does communication cause the present to protract rather than to contract, thereby slowing the becoming of the real, or perhaps even bringing it sometimes to a grinding halt? Communication, so conceived, would seem to short-circuit the being of time. What's more, when the present is allowed to endure, the result can only be existential torpor (Striphas 2010).

Striphas's solution to this is the question itself: "Not all questions are profound, admittedly, but even so, the power of the interrogative lies in its capacity to provoke qualitative changes in reality. It does so, significantly, by providing a resource for posing problems… In the end, isn't it the responsibility of the question not to communicate, but instead to liberate critique from communication itself?" (Striphas 2010). Can the claim perform this liberation for the Internet of Things? I would suggest that they cannot do this entirely. Claims straddle the closed and the open, the virtual and the actual, the present and the possibility of resisting that present. Claims are not identical to questions, insofar as the latter provide resources for problems and for a mode of critique that allows the present to pass into something new. My argument throughout the thesis is that claims are, however, capable of *representing* the present *as a question*. I will argue that they appear as statements but provoke questions. They *straddle*. And in straddling there is room for problems and questions to blossom, between behemoth undersea cables, twinkling streams of wifi, and sniffling, collecting fingers.

1.3 Trajectory

Aims

This thesis poses a sustained reconsideration of an evolving technology — the Internet of Things — along social scientific and philosophical lines. The purpose of the thesis is not to determine whether the Internet of Things is good or bad, nor is it a policy guideline on Internet of Things applications. Rather, the aim of this thesis is to challenge common sense modes of thinking about The Internet of Things and to push the social scientific encounter with this technology toward a more adequate sense of its technical reality. To do this, the thesis will heavily consider what, exactly, the Internet of Things can do.

Outline

Throughout the thesis, I advance the argument that the Internet of Things can be more productively thought with the help of a processual framework, developed particularly through the work of Gilbert Simondon and Gilles Deleuze. The argument proceeds via an examination of the problems of communication, sensing, and actuation. In each case, I propose conceptual shifts that will enable these operations to be grasped, not as problems that are solved in the successive operation of IoT systems, but as problematic structures that exceed such causality. With an eye to gaining an adequate sense of the problematic and processual character of the Internet of Things, I argue that communication can best be understood in terms of modulation, sensing as concretization, and actuation as transduction. Major substantive chapters will be followed by an empirical case study, which I refer to as “Claims”, to express the major tensions and problematics raised by each conceptual transformation I propose. Empirical chapters are not intended to illustrate the theoretical chapters, but rather to show how the *questions* that the theoretical chapters provoke can serve as ways to re-inflect material encounters, which themselves serve as provocations to thought. Thus, the Claim chapters are not intended as applications or exemplars of the arguments proposed in the main chapters, but advance their own claims: that material encounters generate novel problematizations of the Internet of Things, which for their part would not be possible without a processual framework.

With this in mind, Chapter 2 will firstly establish the need to move from a sense of the Internet of Things as a dimension of a specific problem, understood in a negative sense — the problem of neoliberalism, of exploitation, of surveillance, and the like — to a more problematic and thus indeterminate approach. This chapter introduces the Internet of Things as a technical and social system with a rich and rapidly evolving history. Major social scientific and other approaches to the conceptual reality of the Internet of Things will be addressed and briefly responded to in light of the specific theoretical frameworks I am deploying for this project. I develop the idea of the ‘problematic’, through Anne Sauvagnargues’ definition of the problematic as “a heterogeneous tension that produces the conditions of its resolution” (Sauvagnargues 2016, p. 65). I argue that the common sense account, grounded as it is on representational presumptions, positions the Internet of Things in relation to largely homogeneous, incompatible and unresolvable images of possible futures. The chapter concludes by introducing the argument that the Internet of Things' three main operations (sensing, communicating, and actuating) require re-inflection through three different concepts (modulation, concretization, transduction), so as to bring them back into heterogeneous tension.

Chapter 3 will explore what it means to understand communication as modulation. I examine the popular problem of communication as it is framed in IoT discourse as well as in its operation. Communication — between sensors, between layers of processing, between actors, between humans and nonhumans — is regarded as an almost endless vector of political interception. Such a framework, however, has the effect of blocking the movement that would produce the new; the adequately communicated present can only ever report back on a past state of affairs. This becomes an important ontological but also political problem, determining the extent to which the operations of the Internet of Things can successfully claim to communicate a future that is, by definition, open. I borrow from Gilbert Simondon's concept of 'modulation' to reconceptualise communication as a site for the production of difference, which enables the becoming of the present and an openness to the constitutive indeterminacy of the future.

Claim I is the first empirical chapter. It will look at three IoT projects deployed within and just outside of Canberra, Australia: in the emerging 'smart precinct' of Queanbeyan, NSW; at a rural cattle and sheep farm in Yass, NSW; and in the depths of the University of Canberra, tucked away in an undergraduate engineering lab. Each case study explores the active participation of technical objects in the modulation of individuative forces, towards the goal of connectivity but exceeding its homogenizing parameters. From boxes on light poles, to environmental quality sensors, to cow tags in a shed, the operation of modulation and its excesses can be observed wherever communication happens. What emerges from this empirical material is the idea that, when explored with an eye towards disparation, metastability and indeterminacy, the Internet of Things can be understood as something other than a means by which the matter of the world is, at best, represented with fidelity or, at worst, moulded toward the interests of neoliberal capitalism. Its fundamentally differential character comes to the fore and it is from this point that a more adequate consideration of its other constitutive operations can be undertaken.

Chapter 4 examines what it means to reconsider sensing as a process of concretization. I argue that while sensing generates an intelligible form in the guise of identity (of individuals, objects, environments, and events), the production of identity is not in itself a sufficient account of sensing and its transformative capacities. Furthermore, the alignment of sensing with human perception produces a scenario where the utility and ontology of sensing is made equivalent to its ability to produce intelligibility. Yet, as an exploration of Simondon's concept of the milieu will show, the technical operation of sensing ultimately has very little to do with intelligibility, but is rather an act of integration that produces the individual-milieu couple. Internet of Things systems not only instrumentalize the integrative operation of sensing and its ‘smart’ applications, but also evolve and progress according to the convergence of its functions — a process that Simondon refers to as ‘concretization’. I explore sensing as an operation of concretization in such a way as to account for the claim to intelligibility that accompanies sensing, while rendering the ongoing transformation of the milieu open to progress and participation.

Claim II explores three different sensing scenarios — a cattle draughter, a smart building, and an arboretum — and the ways in which ‘smart sensing’ aligns with the tendencies of these technical ensembles towards greater integration with their milieu. Each case study will explore how, and whether, greater internal coherence accompanies these integrative operations, and what novel (and old) relations arise out of them. These instances of concretization reframe the Internet of Things as a technical ensemble that is more fundamentally based in integration than intelligibility. From this perspective, the incompatibilities that mark IoT systems, as well as the successive inventions that enable them to progress, can be attended to with more technical nuance.

Chapter 5 undertakes the final conceptual transformation of the Internet of Things’ technical operations. The chapter considers what it means to conceive of actuation as transduction. Actuation distinguishes Internet of Things systems from simple sensor networks, culminating the previous operations of communicating and sensing into a novel transformation of the world. Typically, these transformations are framed as the point and source of the value generated by Internet of Things systems. Specifically, actuation tends to be seen as an operation by which a set of possibilities is realised, with value being generated in this process of realization. I challenge the presumption that actuation is based in the logic of the possible/real, turning to Simondon's concept of the 'preindividual' to show that such realities can ever only be partial, and to suggest that actuation expresses a partial actualization of a preindividual reality. Actuation can therefore be rethought as the coming into communication of two distinct levels of reality to generate an effect that *exceeds* their original sets of potentials, and that this excess generates *interoperability* in its very operation and structure.

Claim III, the final empirical chapter, explores the extent to which participation in transductive relations becomes possible through experimental IoT systems. Projects developed by Umbrellium, a design consultancy based in the UK that explicitly frames its projects around public participation, will be discussed in terms of their transductive operations. A final reflection from Tom — the farmer from Yass whose cows, sheds, kitchens, buggies and tags have accompanied us throughout the thesis — gestures towards the ways in which the Internet of Things might change, and how it continues to change us, in ways that are, to use his language, 'fuzzy', which is to say partial and with degrees of indeterminacy. Understanding actuation as not entirely actualized and fundamentally participatory — a word I use to indicate the interoperability between the human and the technical — might then allow us to individuate *with* the Internet of Things in new ways.

Finally, the thesis concludes with Chapter 6. Having reiterated the trajectory taken by the thesis, I reflect on two themes that seem to me to be particularly important for an engagement with the Internet of Things beyond the presumptions of representational thinking; namely, the ideas of interoperability and excess. The significance of these themes became especially apparent through the empirical investigations. I can conclude that they offer a sense of the conditions under which the Internet of Things is dependent upon a certain tension amongst its heterogeneous dimensions and its disparate levels, if it is to remain open to the unfolding potentiality of the present.

2
The Problematic Problem of the IoT

What does it mean to speak of the Internet of Things as one of the problems of our time? Immediately it begs the question: 'Is it?' and we find ourselves mired in debates about whether it has succeeded or failed in realising its claims to newness in the technological and social spheres. In this chapter I will build on theoretical efforts of recent years that seek to reconceive the idea of the problem itself (see for example Hynes 2016; Wasser 2017; Sauvagnargues 2016; Savransky 2018; Voss 2018), while addressing the Internet of Things as an empirical artefact with specific technical qualities. The chapter considers what is it about the Internet of Things as a technical system that calls for a different conceptual apparatus, and provides an account of what this different conceptual apparatus looks like.

As I suggested in Chapter 1, the Internet of Things makes a claim to and upon the real. This claim operates both at the level of the individual and at the level of individuation, which is to say that it operates at the level of both product and process. In this chapter, I will indicate the manner in which existing discourse on the Internet of Things advances its claim on reality, and explore how this has affected the academic engagement with the Internet of Things at large. As I will show, when the dominant discourse does consider the IoT as a processual phenomenon — through its focus on artificial intelligence or algorithms, for instance — it nonetheless explains these processes as products of a prior principle. As I indicated in Chapter 1, there is nothing innocent in this ontological focus on product over process, though as I hope to demonstrate in this chapter, that does not mean that there is a sinister underpinning to this ontological framing. However, I do want to argue that something crucial is missed in the priority afforded to the product with respect to process; namely, the indeterminacy of technical ensembles in their communication, to put it in the Simondonian terms that I will employ in this chapter. Ultimately, I argue that the Internet of Things functions on two different but crucially related levels: on the level of the product, via the concrete functions that make it work, and on the level of process, via the ongoing operations which bring it into communication with other operations and produce new regimes of individuation. Understanding both of these levels is necessary to accurately address the capacities of a given Internet of Things system, and therefore to accurately address the Internet of Things as a problematic of our time.

To this end, Section 2.1 sets out the broad technical genesis of IoT systems, situating it within the current techno-political context and describing the Internet of Things' minimal characteristics and functions. Presenting the Internet of Things as an ongoing genesis of technical elements, consisting of both abstract operations and concrete functions, I aim to demonstrate that IoT systems are fundamentally processual in character. Section 2.2 then discusses the association in existing literature between the Internet of Things and wide scale transformations of power. Three major themes in the literature — capitalism, agency, and control — are explored through key thinkers engaged in contributing to contemporary debates. While these contributions have been useful for making sense of how the Internet of Things works as a product and producer of ideology, it will be clear that the Internet of Things as a processual force is in need of further theorization. Finally, Section 2.3 argues that a processual approach — especially inspired by the work of Gilbert Simondon — is best suited to reconsider the Internet of Things in light of its involvement in ontological transformations that cannot be adequately captured by more classical or representational approaches to technology.

2.1 What is the Internet of Things?

Bull in Yass. Image by Author, 2019

It may be useful to begin with an example. There are now smart tags, small GPS nodes, which farmers can attach to the ears of their cows (or any livestock) to monitor their location and movement over time (Pratama et al 2019). The network collects this information and compares it to other collected data which can come directly from the Internet and/or the farmer's own database. It can compare it to the current weather, past observations of this particular cow, collections of data on cow behaviour, feeding and milking schedules, air pollution; effectively any variable which can be meaningfully recorded and communicated to the system can be compared to the recording of the cow

(Michie et al 2020). The system can then send an alert to the farmer, a vet, or any stakeholder with a subscription, when there is aberrant behaviour. Thievery, sickness, and wandering — the three most common problems of livestock management — can all be greatly reduced and controlled with this technically simple system (Agriculture Victoria 2021). At the moment, the system only includes GPS tracked movement, but the possibility of other features, like basic biometrics, has already been pitched (Badia-Melis, Mishra, & Ruiz-Garcia 2015). There is nothing (aside from internet connectivity) that would stop the tags from being connected to other farm infrastructure and be able to perform tasks such as: automatically open gates to a different pasture when it senses that 80% of a paddock has been trodden; administer basic painkillers to a cow when a health issue is sensed; alert the vet to arrive via the trigger of the injection of drugs; or turn on a signal to call over the farmer's dogs when erratic movements and distressed mooing indicate a predator has gone through a fence. Smart tags, of which there are now a number of commercial examples, have been heralded as an enormous innovation to farming practices, from livestock management to progeny control (MLA 2020). There is even talk of opening up smart tag networks for consumers to observe, so that each piece of meat sold in a store can be traced back to a record of a life (Murphy 2021).

This smart tag example is seemingly straightforward and could, with relative ease, be processed in terms of the problem of how useful technology is, and evaluated from the point of view of its ability to produce efficiency gains or inaugurate an unwieldy new regime of supply chain management. It certainly raises significant questions regarding animal ethics and the standardisation of cruelty, as equally it opens the possibility of tracking welfare and ensuring agricultural accountability. The smart tag signals a new economic-technological paradigm. Yet, the social ramifications and nature of the smart tag are less simplistic than they might at first seem. A smart tag system, or even a single tag, appears as one unified technology, but it is made up of many different technical ensembles (Koompairojn et al 2017). For example, one element, the GPS node, is part of an international ensemble of global positioning satellites. And each ensemble comes with its own sub-ensemble: radio frequency repeaters, a power source, a heartbeat, a database of heartbeats, a heat wave. Each element of the smart tag has its own technical reality and milieu, which makes its potentials less determinant than cliche images of technological futures would suggest.

This approach to the smart tag can equally be applied to the Internet of Things as a general technological phenomenon. The Internet of Things is a set of elements with their own distinct and contextual realities. In fact, the heterogeneity of IoT applications, systems and discourses has meant that the question of what exactly constitutes “the Internet of Things” is still contested and often confused (Atzori, Iera, & Morabito 2017). An established part of technical discourse for almost two decades, there are now several formal attempts to define the IoT, at the level of international protocols, standards, and engineering formulae. The Institute of Electrical and Electronics Engineers, an international and highly lauded technical body, defines it simply and straightforwardly: “a network of items — each embedded with sensors — which are connected to the Internet” (IEEE 2014). The International Organization for Standardization draws more attention to the IoT as an “infrastructure” that connects “objects, people, systems and information resources together with intelligent services to allow them to process information of the physical and the virtual world and react” (ISO/IEC JTC 1 2014, p. 4). The European Research Cluster on the Internet of Things agrees that the IoT is a global infrastructure that connects the physical to the virtual, but also that the IoT is “dynamic” and “self-configuring” and stresses that its connections are “seamlessly integrated into the information network” (IERC 2014). International Telecommunications Union (ITU), a worldwide standards body run by the United Nations, offers a more comprehensive definition:

> A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existingand evolving interoperable information and communication technologies.
>
> …Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled (ITU 2012, p. 1).

These broad definitions provide insight into how the IoT is conceptualized by the organisations responsible for managing its protocols, standards and infrastructural needs.

Of course, these definitions are deeply influenced by the stakeholders involved, their explicit and latent goals, and their semantic orientation towards the Internet of Things itself, as either “Internet oriented” or “thing oriented” (Atzori, Iera & Morabito 2010, p. 2788). In a later publication, Atzori, Iera and Morabito (2017) argue that the IoT has been defined within technical literature in terms of six major characteristics: a global network infrastructure; everyday objects; autonomy and autonomicity; intelligent interfaces; heterogeneous technologies; and connecting objects to services (Atzori, Iera & Morabito 2017, pp. 135-136). Ironically, they note that if all six characteristics needed to be present for a system to count as IoT-proper, there would be very few "true" IoT systems in existence (Atzori, Iera & Morabito 2017, p. 136). In the paragraphs that follow, I will discuss some of the more recent attempts to describe, speculate on, and critique what shape today's IoT systems do (and might) take.

Though the most common applications for IoT systems are still largely industrial, pertaining largely to "building and home automation, environmental monitoring or infrastructure management" (Hempel 2016), most available definitions emphasize that the future of IoT systems is in the connection of "everyday objects" (Friess 2011, p. 1; Xia et al 2012, p. 1101; Whitmore, Agarwal & Xu 2015, p. 261; Porter 2019). Indeed, the OECD predicts that the IoT will become "as commonplace as electricity in the everyday lives of people in OECD countries" (OECD 2016, p. 4). This can be partly attributed to a slow but steady shift in the consumer base of M2M technologies and RFID — both formerly expensive and largely industrial — to non-industrial businesses and mass domestic consumption (Bunz & Meikle 2017, p. 23). This progress follows the well-known technology "hype cycle", which posits that all new innovations endure an initial period of high interest and investment, followed by a steep decline into a "trough of disillusionment" before plateauing into common usage. Today the IoT is said to occupy the very depth of this trough, though its ascendance into an accepted technology is predicted to only take two to five years, thanks to steady consumer uptake (Hippold 2020). Whitmore, Agarwal and Xu similarly suggest that the IoT has become somewhat synonymous with consumer services and applications (Whitmore, Agarwal & Xu 2015, p. 261). This has led to a general disillusionment with the term, as it effectively limits the purpose of the IoT to "rebranding for marketing purposes", with IT companies now often re-release existing devices with minor internet-connectivity or interface improvements to then sell them as 'new' IoT devices (Atzori, Iera & Morabito 2017, p. 136). This has led some to insist that other terms, like "cyber-physical systems" or "embedded systems", are more technically and culturally apt to describe the Internet of Things as a technological phenomenon (Denardis 2020, p. 27).

What exactly counts as *the* Internet of Things is thus still contested, a point highly evident in the ways in which it is both revered and critiqued in mass media and some academic publications. Given that the IoT is figured as a technology in which the human can be largely absent from its operation and maintenance, organizations that have sought to standardize and regulate the IoT's technical operations have focused primarily on the "things" of the IoT. For standardization bodies and organizations, the ability to address and call upon "things" addresses the shortfalls inherent in previously developed technologies. The ITU, for example, defines the IoT as a network that "adds the dimension 'Any THING communication' to the information and communication technologies which already provide 'any TIME' and 'any PLACE' communication" (ITU 2005, p. 2). IoT things are seen to be both physical and virtual and are said to have "identities, physical attributes, and virtual personalities" (IERC 2014). The "things" of the IoT may be "any real-world object" that has been enabled to "automatically participate in the Internet and thus be globally discovered and queried" (Lopez et al 2012).

With respect to the IoT's wider implications, advocates and critics alike have focused on the status of "the thing" in its operation. Kramp, van Kranenburg and Lange, for one, praise the relative absence of the IoT itself in its operation; the IoT is "not something you will experience as such itself. What you will see is that more and more … daily activities that were distinct become interwoven in new formats and business models" (Kramp, van Kranenburg & Lange 2015, p. 2). Similarly, the "Internet of No Things" proposes that the ultimate goal of the IoT is to create a "thingless experience" where "objects appear and disappear as needed" (Maier & Ebrahimzadeh 2019). Yet for Higginbotham, the relative invisibility of the IoT to the consumer implies an imminent world of waste and abandoned objects, which he coins the "Internet of Trash" (Higginbotham 2018). Not incidentally, thousands of micro-satellites made for coordinating IoT systems now seriously hinder astronomical observations in some parts of the world (Tung 2019). Satirical engagements with the IoT, such as the parody Twitter account "Internet of Shit", engage precisely with the "thingness" imposed by IoT systems, especially when that thingness becomes absurd, as when toilet paper roll dispensers and cat litter boxes can be monitored and somewhat aimlessly "enlivened" (Internet of Shit, n.d.). In short, such divinations of potential IoT futures cast its vast materiality as either an unbearable burden or a pathway to lightness.

Accounts that shift the focus away from the material dimensions of the IoT are nonetheless similarly preoccupied with its utopian and dystopian potentials. In a process that some have called “shamanistic” (Morey 2016, p. 210), the IoT’s ability to track and sense what would otherwise be impossible, or at least tediously difficult, to recognize in the repetitive and humanly imperceptible movements of everyday, natural and industrial objects is seen to represent a significant capacity; namely, to “make the invisible, visible” (Koreshoff, Robertson & Leong 2013, p. 337). An introductory text published by the MIT Press similarly argues that the Internet of Things:

> offers both a telescope and a microscope into the once invisible world between people, machines, and physical objects. By tagging objects and imbuing them with internet connectivity it’s suddenly possible to not only track the objects and collect new types of data but also combine these data to generate a greater level of information and knowledge (Greengard2015 p XIV).

Though Greengard takes the “invisibility” of mundane reality as a fact, the political implications of this presumption has been scrutinized by other academics. Examining the platforms of Uber, Airbnb and the forms of precarious labour enabled by the “invisible infrastructure” of digital networks, Justin McGuirk argues that the IoT radically reworks the domestic sphere, the purpose of which is increasingly to “cooperate in one great collective data harvest” (McGuirk 2015). He stresses the ideological dimensions of this development, the “use value of which is yet to be sold to the consumer”, who will need to be convinced that the smart homes enabled by the Internet of Things represent more than an “epic power grab by the lords of the network” (McGuirk 2015). For Bill Wasik, in contrast, the liquidation of a mundane space such as the home injects a promising vitality into otherwise lifeless objects, with the potential "to respond to our needs, solve our problems, even save our lives" (Wasik 2013). "What's remarkable about this future isn't the sensors, nor is it that all our sensors and objects and devices are linked together", Wasik argues, "it's the fact that once we get *enough* of these objects onto our networks, they're no longer one-off novelties or data sources but instead become a coherent system, a vast ensemble that can be choreographed, a body that can dance" (Wasik 2013). Yet this dance could equally be choreographed by innocent and curious technologists or by the whims of data barons.

As discussed in Chapter One, my concern is not exclusively with the discursive claims made *about* the Internet of Things, but more primarily with the claims that its technological operations make *upon* the world. In this respect, technical publications on the Internet of Things are instructive. When this project began, the technical discourse on the IoT was substantial. Today it is truly overwhelming. There are many thousands of published technical texts on the IoT, and even more peer-reviewed papers and conference presentations. Early in 2020, the IEEE released P2413, its first draft of an International Standards document for the IoT (IEEE 2020a). IEEE P2413 has taken a number of years, dozens of corporate donors, thousands of contributions, and hundreds of conferences and meetings. As of 2021, the IEEE lists 80 standards related to the Internet of Things, with 45 additional related standards in development (IEEE 2020b). Thus it is not surprising that definitions of the Internet of Things often emphasise qualities which directly relate to its technical protocols. For example: the amount of data it can generate (Atzori, Iera & Morabito 2010), its capacity for inter- and intra-communication (Bera, Misra, & Vasilakos 2017), its ability to function without human interference (Atzori, Iera & Morabito 2011), and its capacity to adhere to ever-changing privacy standards (Urien 2018).

Accompanying this significant technical discourse is continual rhetoric — often inflationary — on the presence and scope of the IoT itself. To be sure, the material and political investment in the Internet of Things has surged in recent years. The European Telecommunications Standardisation Institute calculates that there are now more than 20 billion IoT-connected and enabled devices (ETSI 2020) and estimates that by 2025 there will be 75 billion IoT-enabled devices. Purchases of smart devices such as speakers, air conditioners and security cameras in Australia “grew by 57 per cent in the 12 months to 2018, and is now worth $1.1 billion” (O’Mallon 2020). This had led to some inflationary, even prophetic announcements regarding the technical significance of the IoT. Engineering company Cisco marks the arrival of the IoT as “the point in time when more devices or objects were connected to the Internet than people” (Cisco 2012), a point which we passed some time in 2012. The rhetoric surrounding the present and future scope of the IoT mirrors the way that its evangelists talk about the power of the IoT itself. Much like how the IoT can reveal and recoup what was always already present, the IoT itself is also already here, already everywhere, merely waiting to be instrumentalized.

Inflationary or otherwise, the extensive technical presence of the IoT has led to significant political investment, as well as blossoming tensions. 5G, the latest major telecom network that began rollout in early 2020, was partly developed to accommodate the vast increase of internet connected devices enabled by IoT systems (Wang et al 2018). The UK's recent decision to allow Huawei, the Chinese telecom company, to provide 5G infrastructure has been explicitly criticized as an easy way to allow China to infiltrate UK infrastructure through IoT systems (Sheridan 2020). IoT developments have roused fears about the risk that malicious actors might acquire citizen data, as there are no current enforceable standards for IoT device privacy in Australia (Manwaring & Clarke 2020). Even where a nation's cybersecurity force could introduce counter measures to infiltration attempts, the fear is that once the data is in the hands of malicious actors there is little that can be done to retrieve it (Chen et al 2018, p. 6).

Yet, despite these concerns, the financial and political economy of the Internet of Things continues to grow. The 2019 World Internet Conference featured Chinese President Xi Jinping, whose regime officially named the IoT "the wisdom of the earth" (Sterling 2010), placing the Internet of Things squarely in the centre of his call for a "shared" technological future where every country would equally "shoulder the responsibility for development, meet the challenges and risks, jointly promote global governance in cyberspace and strive to build a community of shared future in cyberspace" (Weedon & Yang 2019). Though most countries have only addressed the Internet of Things in initial policy papers or reports on its potential economic, legal, and social ramifications, bodies like the European Union have dedicated much larger governmental resources to accommodating an IoT future. The EU has had a work group dedicated to the Internet of Things since 2015 and is engaged in seven large-scale IoT projects, which span aged care support, self-driving cars, agriculture, wearable devices, and smart city platforms (AIOTI 2020). While most government responses note the serious security implications, NATO and the US Department of Defence have addressed the Internet of Things somewhat defensively, with papers titled "The Internet of Things: Promises and Perils of a Disruptive Technology" (Tonin 2017) and "What do others think and how do we know what they are thinking? The Internet of Things and the art of mapping a population's thinking, behaviour, and influencers" (Grynkewich et al 2018).

In comparison to other highly industrialized countries, Australia's response has been more muted and, according to critics, thus far inadequate. At a 2015 convention titled "Navigating the Internet of Things", the then-communications minister of Australia, Malcolm Turnbull praised the IoT's "technological imagination" and contribution to "rule breaking" as key to Australia's future in big data, smart applications, and innovation in public and private infrastructure. Yet it was not until 2020 that the Australian government released its first set of legislation regarding the IoT. Even then, the legislation was merely a voluntary Code of Practice for IoT developers, providing guidelines and recommendations to good privacy and security practices (Commonwealth of Australia 2020). The Code is loosely based on a similar publication released by the UK government (Department for Digital, Culture, Media & Sport 2018). Both have been criticized for being too vague, for lacking clear punitive measures for cybercriminals as well as negligent IoT developers, and for being woefully slow to the task of addressing the IoT as a soon-to-be permanent fixture on the horizon

(Manwaring & Clarke 2020).

Publications and organizations that do take the IoT seriously generally do so by emphasizing the impact it will have on the economy — not just in terms of dollars, but also in terms of the way in which industries operate. It is now a well-worn cliché that the IoT brings about the meeting of physical and virtual worlds, “an ecosystem … driven by data collected from devices that sense and interface with the physical world” (OECD 2016, p. 4). Yet the theme has lost none of its appeal and enjoys a central position in what has been called the next paradigm shift in industrial production and economic development; namely, the Fourth Industrial Revolution, otherwise known as 4IR. Following the first revolution of steam, the second of mass production, and the third of digital robotics, 4IR denotes the integration of cyber-physical systems into global industries with a focus on enabling already extensive human-to-machine and machine-to-machine communication networks with the Internet (Schwab 2017, p. 6). Whereas the third industrial revolution was concerned with automating single machines or systems, the fourth “encompasses end-to-end digitalisation and data integration” and relies specifically on Internet of Things platforms and systems to realize this holistic digitization (Swinburne 2019, p. 3). 4IR depends upon the Internet of Things because its revolution in production methods relies on integrating with non-digital systems in a way that “blur[s] the lines between the physical, digital, and biological spheres” (Schwab 2015). As a crucial point of connection between different realms, the Internet of Things is thus explicitly reliant on the pre- existence of a swathe of other technologies. For this reason, the IoT is seen by some commentators as simply an extension of the Internet into “a range of objects, processes and environments” (Galle, Nitoslawski, & Pilla 2019), or an “evolution” of existing technologies into more distributed and Internet-connected networks (Whitmore, Agarwal, Xu 2015, p. 262). These discourses position the IoT as an obvious next step in telecommunications, one largely already present, at least in terms of its enabling conditions. This is perhaps why, in 2019, a smart city consultant said to me very plainly, “It is now no longer a question of whether we will use the Internet of Things. It’s a matter of when” (Interview with Michael Schultz, May 2019).

What is striking is that the existence of the IoT as a technology, despite all the hype, does not have the strangeness that one would expect from a new technological paradigm. In part, this is because it is not entirely technologically novel. As suggested, the IoT relies on an extensive network of existing telecommunication and other electronic technologies and networks. Its technical interventions are thus in many ways already familiar to us, perhaps most obviously in its underlying infrastructure and hardware. In 2019, Telstra, a major Australian telecommunications company, boasted that its early IoT-friendly network, a precursor to the 5G rollout, had connected “over 3.2 million devices … to our network and an average of 2000 more being added every day” (Telstra 2019), implying a world already made up of IoT or IoT-able things. IoT systems rarely require fundamentally novel hardware, and almost always build on existing hardware devices and infrastructures (Whitmore, Agarwal & Xu 2014, p. 263), especially and originally in RFID.

In RFID (radio frequency identification), an object is given a chip which either passively (constantly) or actively (on request) emits a unique radio frequency, which can then be identified by a reader. As far back as World War Two, planes performed a rudimentary version of this radio communication by swooping their wings while approaching an air base, varying their radio signal to identify themselves as friendly (Minerva, Biryu & Rotondi 2015, pp. 7-8). Today, consumers are most likely to encounter it embedded into security tags on expensive goods, or embedded in ID cards to grant access into buildings. RFID, and radio communication more generally, are commonly marked as the origin point of the IoT. This is in part due to it becoming more low-powered, more distributed, and eventually connecting to the Internet and local intranets (Jia et al 2012). As well as providing a mode of communication, RFID also provides a method of identification that is accurate and low cost. This enables a "tag and track" paradigm of communication and computing infrastructure that can, in principle, be extended to "virtually every object on Earth" (Minerva, Biru & Rotondi 2015, p. 18). RFID's material agnosticism, paired with its radio-based communication protocols, contained the conditions necessary for the IoT's emergence. RFID translated directly into industrial settings, where RFID networks enabled "machine to machine communication" (M2M): the addition of two-way communication protocols to RFID-tracked objects allowed industrial machines to track and respond to the status of other machines, products, or resources within an industrial setting (Granell 2020, p. 403). Kevin Ashton's invention was, somewhat simply, the extension of this paradigm out of industrial intra-nets and into the Internet. The Internet of Things has thus developed less by way of progressive invention and more by way of opportunistic agglutination, borrowing heavily from existing technological regimes, protocols, infrastructures, devices and softwares. The claim that IoT systems do something new, then, lies less in their material or broader technological reality, and more in the way in which these pre-existing technologies are put towards novel processes and technical operations.

We can note that the definitions and histories of the IoT covered to this point all emphasize communication and sensing as the two major technical operations that distinguish the IoT as a new paradigm. Here I part with these more popular understandings of the IoT, which would count sensor network systems as IoT instances and implicitly include things like personal health monitors and weather stations, and instead define the Internet of Things as a system which must also involve actuation. While there have been extensively intricate sensor networks for decades, it is only with the IoT that these networks can actuate according to their internal semantic data architectures as well as according to Internet-enabled repositories. Actuation is, at best, a broad conceptual term. Technical definitions are vague out of necessity, as actuation can cover "any mechanism by which an agent acts upon an environment. The agent can be either an artificial intelligent agent or any other autonomous being" (ITU 2006, p. 11). Often, actuators are presented as the 'doers' of the sensory system. As Whitmore et al suggest, "(w)hile sensors 'sense' the state of an environment or object, actuators perform actions to affect the environment or object in some way" (Whitmore, Agarwal & Xu 2015, p. 264).

What constitutes actuation in practice is, effectively, entirely arbitrary. A smart home, for example, would consist of a wide variety of actuators and actuation operations — text messages when the fridge is out of milk; turning the AC on and off according to a pre-set temperature; calling the police if an intruder is detected; watering the garden when the weather is predicted to be dry and hot. Even this final example — of which there are now numerous consumer and industrial examples (Mahadevaswamy 2018) — is made up of its own series of actuations: at 6AM the smart home system is prompted to refer to the local weather report, which actuates a computing environment of prediction and waiting. If the report indicates hot dry weather, the system actuates a "hot dry weather" protocol for the watering system. After physically turning on the water valve to release water into the garden's drip hose, the smart home would continue to actuate the weather-checking protocol to determine when to rotate the water valve back to its off position. In more sophisticated systems, there would also be moisture sensors in the soil which would feedback into the smart home to signal when the soil reaches a point of saturation, and to turn on the drip hose on days when the soil has gone dry despite reports of wet weather.

Without actuation, these myriad operations would be limited to a simple report, accessible by a smartphone or browser interface, leaving the worlds of the garden bed, the watering system, the home and its inhabitants to participate in much different ways. As prosaic as this scenario may be, the importance of actuation in grander examples — automated mining operations that rely on IoT systems to shut down operations and sound the alarm when hazardous conditions are sensed — would show a similar granularity of actuative operations, and would also show how an IoT system's novelty relies on its participative powers, powers that come to greatest light through actuation.

I would argue that it is more meaningful to define the IoT by its capacity to instigate environmental transformations using its own technical capacities — in other words, by its ability to *actuate*. This greatly narrows the field of IoT applications, eliminating, for example, public wifi networks and weather stations, and focuses on the greater technical trend in IoT systems to achieve a level of autonomy and independence from human action by merit of their own actuations. Autonomy — and its conceptual partner, automation — are also an important aspect of "smart" technologies which, as we will see, are increasingly synonymous with (and often require) IoT systems, though this tends to obscure their IoT roots in favour of the more consumable concept of "intelligence".

Delimiting the IoT to those systems that actuate also opens it up to the problems and claims presented by encroaching forms of smartness, and will allow me to explore the technical operations which underpin these all too familiar technologies and promises. Furthermore, as I will gradually show, the technical operation of actuation is a necessary aspect of the kind of processual power that emerges from IoT systems - that is, actuation is necessary for the operation of the *claim* of the Internet of Things. I am not arguing that systems without actuative powers should be dismissed as instances of the Internet of Things. Yet, while I do not ignore them in my discussion of the current sphere of IoT systems, I do not include non-actuating technologies in my empirical analysis, nor do I consider them in my theoretical arguments. Crucially, making actuation a feature of my definition of the Internet of Things enables me to emphasize the processual capacities of IoT systems, with an eye to pushing our apprehension of such systems toward a more process-oriented perspective.

In sum, the Internet of Things is, at this moment, being deliberately seeded into commercial enterprise, public policy, cultural conversation, and critical infrastructure, especially in Australia. It would not be a stretch to say it is now the subject of common citizen concern, even if it appears under other monikers of smartness, automation, or connectivity. For all their anticipatory pronouncements, what such discourses tend to obscure is that the Internet of Things, as something that has clearly already arrived, requires an extensive array of pre-existing technological capabilities. As I argue, an analysis that is adequate to the Internet of Things requires a sharp attunement to its technical genesis.

2.2 What kind of problem is the Internet of Things?

As I have outlined above, the Internet of Things is not a single technological object, but rather a broad technical paradigm, an assemblage of old and new bits of infrastructure, a way of thinking about the future, and a revolution of sorts with serious political and economic consequences. Given this significant and far- reaching influence, one would expect an equally serious academic and theoretical engagement with its operations' more general ontological weight. Indeed, there have been some volumes dedicated to the Internet of Things and more that usher the IoT under the general problematics of new automated technologies. And yet, in the social sciences, theoretical engagements with the Internet of Things as a distinct techno-social object have been uneven and somewhat classical in orientation. My concern is that engagements rooted in well-established sociological epistemologies and ontologies risk negating the real novelty of the IoT, or redirecting it towards a validation of established paradigms. To be sure, there is much in the IoT that speaks to and affirms greater social and technological trends; considering its extensive reliance on existing technical infrastructures, this should hardly be surprising. However, the IoT also offers something new to social science, technology studies and the world at large. I aim to show that, viewed from the point of view of its processual character, it has a genuine novelty that analyses based in more classical and representational frameworks characteristically miss. The following chapters will explore what this novelty might be, and how it emerges from IoT ensembles and operations.

Before the potentials and novelties of the IoT can be explored, however, it is necessary to first establish how the IoT calls upon and, in some cases, resurrects significant and critical trends and theoretical dispositions in the social sciences. This work has, in part, already been done by other authors. Perhaps one of the better-known sources is Deborah Lupton's thematic review of the sociological literature on the IoT and its "social imaginaries" (Lupton 2020). Paying attention to these imaginaries is important, she argues, because they "give meaning to the IoT' as a whole, and "invit[e] engagement with them in certain ways"; usually, she argues, in a way that "designs out the human" (Lupton 2020, p. 3). Speaking to a broad array of social research on the IoT — spanning cultural geography, science and technology studies, environmental studies and human-computer interaction — Lupton identifies common utopian and dystopian narratives that mark the way the IoT is imagined as an element of future social life. In its utopian guise, the IoT is imagined as part of a greater shift towards global efficiency, with the potential for the IoT to become "symbiotic" with human needs and integrate into increasingly "smart" ensembles of urban, agricultural, industrial and personal systems (Caprotti & Cowley 2019; Sadowski & Bendor 2018; Taylor, Buck & While, 2017; White, 2016). Whether hopeful or cynical, the focus in existing literature, Lupton suggests, is on the new methods of control introduced by the Internet of Things or at least its extension of existing methods in ways that are at best, useful, at worst, insidious (Freed et al. 2019; Tanczer et al. 2018; Vella, 2018).

Lupton's review is significant but certainly not exhaustive. In particular, her characterisation of the literature as largely based in a "human-centric approach that also acknowledges the role of non-humans" undoubtedly informs the conclusions one might draw about this field of research. That is to say, the way that the relevant literature is identified and schematised has implications for the manner in which we might grasp the genuinely productive capacities of the Internet of Things within contemporary reality. While Lupton alludes to the 'entanglement' of human and non-human entities, her principal concern is with the capacity of existing literature to shed light on largely human problems; namely, the "dominant social imaginaries giving meaning to IoT technologies, aspects of the social, political, spatial and cultural contexts and implications of deployments of the IoT, and the details of people's lived experiences with these technologies" (Lupton 2019, p. 2). No doubt this concern with the questions of social imaginaries, instrumental applications and lived experience does dominate much of the existing literature. Yet, beyond prescriptions for future research directions that would effectively extend these preoccupations into wider contexts (e.g. the Global south), I suggest that a re-engagement with existing tendencies in the literature will produce a more potentialized sense of the technological and social novelty of the IoT itself.

With this in mind, I would like to suggest that there are three broader trends in the literature on the Internet of Things (and adjacent "smart" technologies) that address it as a philosophical and social scientific problem, without entirely excluding or glossing over its technical genesis. Specifically, these approaches characterize the Internet of Things as a particular type of problem whose solution can be found within established social scientific frameworks. First, there is the critical argument that IoT systems represent, even generate, a new mode of capitalism, or that they extend existing modes of capitalism into something potentially more pernicious and entrenched. Second, there is the approach which positions the Internet of Things as a challenge to established understandings of ontology, introducing new ways of intervening in modes of human agency and biological capacities. A third perspective includes the now well-established arguments that IoT systems introduce new modes of power and subjectification as a result of its networking capacities.

In view of the dependence of each of these accounts on classical, representational presuppositions, it is more than likely that they will continue to have strong purchase in the social sciences and in broader explorations of the ideologies, desires and threats represented by the Internet of Things. For this reason alone, they deserve a degree of critical attention. Moreover, while I will suggest that, ultimately, these accounts inadequately grasp IoT systems in the processuality of their being and operations, they nonetheless open important questions about capitalism, ontology, and power respectively. As such, they offer a starting point for a more fundamental exploration of the problem of the technical genesis of the IoT. Namely: for the question of the potential claims of the IoT, functioning as it does at the intersection of the operations of capitalism, the ontological transformations wrought by technical means, and the modulations of power associated with them.

To consider in more detail the first perspective, critics who place this particular technological innovation within the broader context of late capitalism tend to evaluate it against established images of social relations and ideas of freedom. Nick Srnicek, for example, considers the IoT as one of the vital tools for entrenching the exploitative practices he associates with “platform capitalism” (Srnicek 2017a). In this respect he aims to counter the optimism of popular authors such as Jeremy Rifkin, who argues that because it negates the need for historically exploitative conditions of human labour (e.g. factory work) and reduces the marginal cost of production effectively to zero, the Internet of Things will eventually replace the geopolitics of competitive capitalism with a collaborative frame of reference (Rifkin 2014). According to Rifkin, this new era of post-capitalist collaborative commons is also heralded by the greater participation that smart cities will afford to citizens with respect to public data gathering and decision making (Rifkin 2014).

In stark contrast to this optimistic evaluation of the potentials of the Internet of Things, Srnicek identifies the Internet of Things as one of the fundamental tools for extracting both data and free labour, both of which are crucial raw materials of 21st century platform capitalism. Srnicek (2017b) stresses that sensor networks, cloud storage facilities, and arbitrary actuators all work to generate and process data — big and small — that digital platforms like Amazon, Facebook and Uber rely on to generate value out of consumer interactions. Data extraction is not limited to tech companies either, Srnicek points out; as data gathering becomes a more normalized globalized business practice, other sectors will increasingly adopt platforms to manage data, customer relationships, and profit maximization. Srnicek uses the example of John Deere, an agricultural company that now has an established IoT platform for tracking and maintaining farm equipment, connecting farmers to other supply chain actors, allowing the company to "gain the advantage and beat its competitors, as capitalism demands" (Srnicek 2017b, p. 255). And for Jathan Sadowski (2020, p.564), the Internet of Things might just as readily be called the "Internet of Landlords", given the extent to which he sees it functioning as a mechanism of rentier capitalism, enabling "new sources of rent, new infrastructures of rentier relations, and new mechanisms of extraction and enclosure."

Similarly, focusing on the level of infrastructure, some have argued that the intensification of massive online data processing — required for IoT systems to function at scale — is also a site of social control. Munn's (2022, p. 986) analysis of smart city communication infrastructure argues that the combination of "cloud" (centralised) and "edge" (localised) computing signals "a more comprehensive saturation of control across the field of the everyday". Effectively, smart city IoT systems that use both low-powered high-fidelity data processing systems, as well as high-powered low-fidelity systems, can complete the power circuit between centralised and decentralised modes of surveillance. Approaching the problem with more nuance, Amoore (2018, p. 20) argues that "(i)n the cloud the promise is that everything can be rendered tractable, all political difficulty and uncertainty nonetheless actionable". Its strength and its lure, she argues, is that it "renders geopolitics infinitely reworkable", settling disputes and producing solutions in "a kind of geopolitical cloud chamber". Certainly, the involvement of enormous state apparatuses and corporations in cloud computing pose important questions to the study of IoT systems, which are being addressed to some extent at least in the emerging social scientific study of Cloud computing (see especially Amoore 2018). What can be noted at this stage is the trend in some publications to align data processing and digital infrastructures with intensifying modes of surveillance and control.

Beyond the increased exploitation of workers, the extension of the Internet of Things into diverse aspects of daily life has also been regarded as signalling a steady degradation of personal freedoms. Some suggest that the mass data collection services that make platform capitalism possible constitute near-constant surveillance (Srnicek 2017b; Andrejevic 2020). According to Mark Andrejevic (2020, p. 242), the "so-called Internet of Things promises to transform our lived environment into a fully monitored one" and, ultimately, a state of "automated surveillance". Some of this surveillance falls into the cybercriminal sector; we could think here of the case of the casino that was infiltrated through an unsecured smart thermometer (Schiffer 2017) or the baby monitor that was hacked to try and threaten the parents with kidnapping (Green 2018). However, the majority of such surveillance is accomplished by large companies that normalize data collection through their advertising and user agreement practices. Shoshana Zuboff (2015) calls this naturalized data collection "formal indifference": companies are indifferent to the identities of the subjects from whom they collect data, to the extent that the data they produce can be captured and put to work, usually for predictive algorithms used for advertising. On top of lucrative data extraction, what Zuboff (2015) calls "surveillance capitalism" relies on behaviour modification via data extraction and actioning, which effectively allows companies to guarantee outcomes rather than simply improve them. Business becomes a competition of delivering guaranteed futures, where “surveillance capitalists make the future for the sake of predicting it” (Zuboff 2019, p. 18). Forget the subtle digital nudge, Zuboff warns; the goal is not to automate information flows, but to “automate us” (Zuboff 2019, p. 19). Zuboff (2019) thus diagnoses an expansive instrumental power that will not be abating anytime soon, especially with the concatenation of the Internet of Things and 4IR into international markets. Similarly, Andrejevic (2020) states that the increasing presence of IoT sensor networks means that people are more likely to assume that sensing is happening, which actually makes them less likely to notice or care about surveillance practices. This, he suggests, produces subjects and bodies that become more economically productive by being more docile in the face of behaviour monitoring (Andrejevic 2020, pp. 247-248). For this strand of critics, the Internet of Things serves as the handmaiden to ultimately worrisome capitalist trends.

It is at a more fundamental, ontological level, that the second stream of scholars locate the threat of the Internet of Things, given the capacity of new modes of digital automatisms to radically transform subjectivity and the social relation itself. Bernard Stiegler, one of the better-known philosophers of automation and technology, has been a major influence here, specifically his comprehensive engagement with digital capitalism and, more fundamentally, the thought of automation. Stiegler (2017, p. 2) addresses the problems of the “new economy of data” as a “new automatism” which, rather than an anthropocene, produces an “entropocene”: “a period in which entropy is produced on a massive scale” via the instalment of networks of “closed systems”. Stiegler (2017) argues that these new closed technologies short-circuit social relations that would otherwise produce opportunities for knowledge production and a counterbalancing "negentropy". Stiegler (2020, p. 75) counts the IoT — along with GPS, online search engines and smartphones — as technologies that have an effect of "ruining attention." Yet beyond increasingly commonplace and often trite commentaries on digital distraction, Stiegler provides a sustained account of the way in which the realisation of the essence of technology in the late capitalist stage changes profoundly the status of memory and knowledge. "What has been liquidated and automatized is knowledge" itself, Stiegler (2017, p. 2) claims, "so that in fact it is no longer knowledge at all, but rather a matter of closed systems". Stiegler suggests that this closing off of knowledge production leads to a scenario where those who control these closed systems gain undue control over its users and their own automatisms; a smart home interface, for example, directs the occupant towards certain "smart" or "efficient" or "environmentally conscious" decisions regarding the desired temperature of their home, or even what other products to purchase in quest of this more conscientious way of living. On a deeper level, the "layers upon layers of automatic behaviour" that characterize IoT systems and most digitally networked technologies have the ability to outpace the brain's reasoning functions by a factor of 4 million (Stiegler 2015), effectively short-circuiting the human memory function and replacing our ability to *retain* memories with a predictive *protention* of the network (Stiegler 2017, p. 8). A technology such as the Internet of Things thus represents for Stiegler a potential erosion of our otherwise collective relationship to ourselves and the things of the world.

Extending Stiegler's ontological concerns about predictive technologies into geographical contexts and particularly smart urban design, Mark Hansen and Jordan Crandall raise concerns about the capture and transformation of human modes of sensing through technologies such as the Internet of Things. Crandall's *The Geospatialization of Calculative Operations* (2010) is a resounding critique of celebratory rhetoric on so-called smart environments, networks and devices, and specifically their capacity to increase citizen agency and access to the data-driven commons. Rather than creating a way for humans to access the data produced by smart cities and buildings (and therefore give back to the commons the fruits of the labour that were extracted from them), Hansen (2014, p. 39) argues that they create a "tacit atmosphere of sensibility for action and capacities for data- gathering and analysis". This atmosphere is fundamentally indirect; rather than being the main point of experience and attention in the smart city, it acts as a "cognitive, ontological, and experiential supplement for the simplest forms of ordinary routine" (Crandall 2010, pp. 87-88). In Hansen's extension of Crandall's argument, this atmosphere is also said to "open possibilities for precognitive shaping of — and capture of information about — our actions or likely tendencies for action" (Hansen 2014, p. 39). Hansen (2014, p. 41) points the finger at cybernetics for providing the technical basis for such possibilities: "(i)t is as if micro-computational sensors literally wrested these processes from their natural embodied context and made them independently operable and accessible". This operation allows "forethought" to be manipulated as a variable on an institution's own time (rather than the time of the body), or at least according to the time of prehension rather than apprehension. Hansen (2014, p. 41) claims that "this operation is [...] literally premised upon the bypassing of consciousness". The implication is that when one bypasses consciousness, one bypasses a vital avenue for intervention and resistance: "(t)he sway exercised by contemporary capitalist institutions is a function of their capacity to control the time of experience and is thus a site for potential political struggle" (Hansen 2014, p. 41).

The focus in such literature on the threats posed to human agency and autonomy ultimately position technology as fundamentally at odds with human capacities and long-term interests. Technological progress and new infrastructures of sensing are believed to enrol the human towards technical purposes, at the expense of human access to the real (Stiegler 2017), creating techno-ecologies which fail to distinguish between technical and biological sense mechanisms (Crandall 2010) and generating indirect sense atmospheres for technological harvesting (Hansen 2014). The Internet of Things is thus considered a veritable force in contemporary life, though one that can never truly be considered as co-constitutive with human life.

While such critiques have an important focus on the varying capacities to affect and be affected within different ensembles, they make the mistake of seeing the human capacity for sensing and differentiation as separated from, and diminished by, technological capacities. Stiegler, Crandall, and Hansen do not vaunt the biological as the ideal or only model for "good" sense, and they take care in attending to the specific technicity of various technological apparatuses. They are, however, all motivated by an anxiety that bypassing biological sense (and the consciousness which depends on it) will end badly for the humans involved. This is a problem that Luciana Parisi (2017) captures in a much more nuanced way. Parisi is interested in what is coming out of the relatively new collaborations between computer science and biology. She argues that:

> computational materialism in design is the manifest image of a technocapitalist culture turning the mechanization of deductive reasoning into a dynamic logic of computation whose rules are established by the indeterminate potentialities of physical, biological, chemical behaviours and their complex interactions (Parisi 2017, p. 76).

Parisi argues that computation has been "naturalized" by the inflection of design thinking into computer science; for example, when biological self-organization is used to inform AI, the process of design involves the application of a biological logic onto a computer program. This naturalization of computation shifts the deductive model of reason/rationality towards an inductive model of reason/rationality, because emergent environmental data is used to build theories of computation, rather than computational theories and methods being used to capture or make sense of environmental data. Parisi argues that this implies the production of a new concept of "Nature", as a result of the "naturalization of computation", itself an instance of the new "ecological view of power" which Parisi sees emerging in new bio-algorithmic ventures (Parisi 2017, p. 75). Parisi gives a more coherent critique of the trends picked up on by Stiegler, Hansen and Crandall, in part because she is cognizant of the ways in which contemporary computation and biological processes (human or otherwise) borrow from each other in novel ways. This allows for a much more nuanced view of power as it may be operating within vast IoT networks.

The third theoretical tendency I wish to discuss characteristically focuses on the new forms of power that critics associate with the IoT and adjacent technologies, especially in relation to their networking capacities. The concept of the network in philosophy, sociology and Science and Technology Studies (STS) has shaped much of the discourse around ICT and questions about what these technologies actually do. It is difficult today to speak of networks in the social sciences without deferring or referring in some way to Bruno Latour's (and others') Actor Network Theory (ANT). ANT gestated in the late 70s and 80s in France as a solution to the disciplinary and ontological gap between the natural and social sciences. What bridges this gap is not a new unifying theory, but a method of mapping the relations within collections of actors. Described as "distinctly materialist" and "radically constructivist" (Muniesa 2015, p. 80), ANT has taken preoccupations with truth, and especially scientific truth, materiality and signification and combined them into a method which refuses to privilege particular kinds of actors over others, puts these actors into a web where how they relate is of utmost importance, emphasises that without continuous enactment these webs of reality effectively disappear, and finally puts to the researcher the fact that "reality is not destiny" (Law 2006, pp. 4-5) any more than structure is inevitability. In its heyday in the 1990s, ANT was characteristically figured as an attempt to ease the "dissatisfactions" produced by postmodern anxieties: that is, the dissatisfaction of abstraction both at the level of structures and at the level of the "flesh-and-bone local situations from which they had started" (Latour 1999, p.17). For its part, the idea of postmodernism has been extended long beyond its natural 'best by' date and continues to surface in, among other things, debates around the relationship between technology and philosophy. In academic scholarship, for instance, Graham Harman opened a

2017 book on Alfred N Whitehead with the proclamation that philosophy has endured “several decades of cloudy postmodernist weather”, from which we are only now being delivered, in large part due to the Whiteheadian reinvigoration of “the spirit of mathematics, natural science and radical Enlightenment” (Harman in Debaise 2017, p. viii). In any case, understanding new technological systems and their significance to philosophical thought is being posed as a problem that is strongly suited to these newly clarified ontologies.

Similarly, Object Oriented Ontology (OOO) has been posed as a fitting theory to analyse the Internet of Things, considering its focus on both objects and ontologies (technical and philosophical alike) (Mitew 2014; Lindley, Coulton & Akmal 2020). OOO was developed as a result of a symposium — featuring the four thinkers Quentin Mellasioux, Ray Brassier, Ian Hamilton Grant, and Graham Harmon — which universally rejected the philosophy of ‘correlationism’, or the idea that objects only acquire reality and meaning through their relation to humans (Lindley, Coulton & Cooper 2017, p. 2848). OOO instead argues that there is a reality to objects that supersedes human perception, and therefore cannot be grasped by it. Thus, not only do objects have their own reality, but that reality is equally ontologically important to human reality. This “flat ontology” approach has been enthusiastically taken up in some domains — like Tim Merton’s OOO-inspired theory of the hyperobject (Morton 2013), and Ian Bogost’s alien phenomenology (Bogost 2012) — and heavily critiqued in others, especially on the grounds that it enables “a contemporary culture that denounces the idea that human beings can — even should — actively reshape the world in their own interests” (Charlesworth 2012).

According to Latour, ANT is not so much a theory of the world as “a method to deploy the actor's own world building activities … ANT concentrates attention on a movement” (Latour 1999, p. 15, 17). Again, this focus on movement and world building seems appropriate to a critical analysis of the Internet of Things; if an Internet of Things system can claim to act on life according to its movements, then surely a diagram of those movements, using ANT, would give useful insight not only into how the Internet of Things functions as a network-maker, but also what kinds of worlds it claims to build. The problem it poses to a processual reading of the IoT, however, lies within its reliance on the network. “The network” as analogy and ontology sits somewhere between being and process. One could argue that networks are the being of process. Indeed, ANT has been heavily critiqued for the way in which it anthropomorphizes exactly what it claims is non-human (Whittle & Spicer 2008). Despite the fact that a phenomenon like the Internet of Things seems perfectly suited to a network-based analysis, theories like ANT and OOO — while successful at undoing the traditional approach towards humans and non-humans, and therefore a useful resource for considering technologies which “network” reality in new ways — rely heavily on the subject/node, and ultimately poses the problem of technology in a way that leads to an ontological dead end. In network ontologies, there is the brute (but always speculative) realism of all objects, and OOO’s job is to bring these realities, however belatedly, to philosophical light. This approach, while helpful for understanding pre-conceived networks, subjects and nodes in a dynamic way, tends to pass over the becoming of those realities.

I have been suggesting that dominant approaches to the Internet of Things see it as an issue of control — whether that control be relegated to the hands of a select few, wrested away from the human, or distributed to actors in a vast network. The preoccupation often boils down to a few key questions: who has it, how it is done, and to whom does it apply? Michel Foucault's work on control has yet to recede from the Western sociological scene since his heydays in the 80s. Foucault's work has allowed the social sciences to think about control not as a matter of sovereign power exercised over peasant bodies, but as a method or mode of production, and especially the production of the subject. The Foucauldian approach has been especially helpful for technology studies. In part, this is because the very word "technology" is often taken to immediately imply a kind of master-slave relationship between the user or designer of the technical object and the object itself. But with a Foucauldian reading, the question of technology and control shifts from a question of oppressive objects and oppressed bodies and towards a question of the production of relations and the boundaries that bring the technological subject into being. A Foucauldian reading, for example, might see the Internet of Things as a kind of super- discursive machine. In creating the "visibility" of objects and bodies, it defines the discourses around them, and the "actuation" of that visibility conditions their articulation in the world. It produces a subject that can be controlled through new forms of self-surveillance (e.g. smart homes), self-discipline (e.g. personal health technologies), and so on. Popular readings of the IoT have not failed to pick up on this, though there has been a failure to treat this idea with nuance. "The Internet of Things will make you poor, surveilled, and alone" (Jones 2014) is joined by increasingly Orwellian visions of our impending technological future.

This is the diagnosis of modern society that Deleuze addresses in his increasingly popular paper, *Postscript on Societies of Control* (SoC hereafter), a ten-page piece written by Deleuze in the winter of 1992, years before the Internet of Things got its name. Deleuze specifically takes up Foucault's notion of disciplinary societies and argues that, yes, there has been a shift from sovereign power to discursive power. But, as Foucault wrote about disciplinary societies, they were already the state of history from which we were already becoming different. Whereas Foucault's theory was a problem of confinement, his own theory is a problem of modulation:

> Confinements are molds, different moldings, while controls are a modulation, like a self-transmuting molding continually changing from one moment to the next, or like a sieve whose mesh varies from one point to another (Deleuze 1992, p. 4).

Subjects do not move between discrete discourses or spheres, but are subjected to continuous processes and practices of modulation; mastery is no longer a goal to be achieved, but something to be eternally worked at. Education, for example, does not stop at the last years of secondary or tertiary schooling, but is something that we do over and over through things like vocational and workplace training. As a result, individuals can be treated instead as "dividuals": collections of vital statistics and capacities that, while constantly mutating, are always within the same universal regime of control (Deleuze 1992, p. 5). The "molehills" of discursive capitalism turn into the "coils of a snake"; rules-heavy linguistic games are replaced with the endless tides of communication "surfing". As the Deleuzian scholar Brian Massumi puts it, it is a shift from communication to "infinite communic-*ability*" (Massumi 2002, p. 142).

Such theorizations of modern ICTs as purveyors of a new brand of continuous control have been on the social science scene for almost two decades, though the uptake of SoC into broader social science is relatively recent — and often references the Internet of Things specifically (see Williams 2015; Sadowski & Pasquale 2015; Bunz & Miekle 2017; Braatvedt 2020; Erkan 2020). Of these, Alexander Galloway's *Protocol* (2008) in particular is applicable to the way in which the IoT has arrived on the scene. Galloway argues that due to the mass decentralization of network technologies, modern control appears as the technical protocol. Decentralisation is a common characteristic of most emerging large-scale networks, and especially in Internet of Things architectures (Kortuem et al 2009). "How can control exist after decentralisation?" Galloway asks, and his answer is the protocol. *Protocol* follows SoC's line of argument and shows that old disciplinary boundaries (the rule) have been replaced with regimes of continuous variance (the protocol). When there is no centralised mode of governance, the protocol takes on the task of control; protocols are "a solution to the problem of hierarchy" (Galloway 2008, p. 7). Galloways asks us to compare a speed bump to a speed limit sign or a police car waiting in the bushes. Which is a protocol, and which is a rule? Speed limit signs and police cars are rules: the sign states the rule, and the police car enforces it. Both are clear expressions of a centralised law ("do not go over 40km"), and enforce a written hierarchy (the driver is below the law, below the speed sign, and below the police). A speed bump, on the other hand, only references a rule ("the speed limit is 40km"), and instigates the driver to mould their behaviour around a request: to slow down and drive according to the terrain produced by the bump (Galloway 2008, p.241).

Behaviour modification of this kind has also been identified in large scale IoT systems, most commonly in smart cities and other public digital environments. Pali & Schuilenburg (2019) identify modulation as one of the key features of the smart city. They use the concept of modulation in the psychological sense of attenuating the “mood and behaviour of the users” (Pali & Schuilenburg 2019). They immediately pair this sense of modulation, as an aspect of constant manipulation, with “neoliberal logic” and surveillance. Neoliberal logic in this instance accords with Foucault’s critique of controlling movement and restricting access: “the smart city seeks control without stopping or hampering the flow of visitors in public space” (Pali & Schuilenburg 2019). The concept of the “nudge” is often used as an example of how to incite particular behaviours which are in line with public (administrative, corporate, governmental, police, infrastructural) goals without having the feeling of tyranny or absolute direction. Nudging and modulation are pitted against the concept of “hard” control, and instead are examples of “soft” control, issues through “providing cues”, the gentle nudge on the shoulder, given by an automated text message reminding you to drink more water or go for a walk. Pali & Schuilenburg point out that modulation in the smart city is the way for city governors and designers to “control … without hampering or stopping the flow of visitors in a public space” by “providing cues for alternative behaviour” (Pali & Schuilenburg 2019). The cue comes to be the mode of modulation: the mood or behaviour is given an apparatus which brings with it the promise of a different present in the form of an alternative future. This contrasts to earlier forms of city governance which deliberately “designed out” unwanted behaviour (via surveillance, hostile architecture, and implicit punishment or harsh consequences), all of which operate by hindering flows in public space (don’t cross the road, don’t steal from this shop, don’t sleep here).

Now, Pali and Schuilenburg argue, the approach is more like a volume knob than an on/off switch. Turn the volume up or down, or change the radio station, but keep the music playing.

Pali and Schuilenburg go on to argue that smart cities, and specifically the operation of modulation, is not a detractive operation but an additive one: "the smart city not only reproduces the social order, but also produces new social categories through new forms of smart governance" (Pali & Schuilenburg 2019). The additive approach is also in line with modulative approaches to the social, where nothing is prohibited but is rather re-tuned or guided elsewhere. It is not the elsewhere itself (the alternate behaviour, the alternate mood) which characterizes smart cities. What characterizes smart cities, according to Pali and Schuilenburg, is how "the social body is modified, purified, sorted and thus governed according to what works best in order to 'de-risk investment in smart cities and communities'" (Pali & Schuilenburg 2019). Ultimately, the authors decide that smart cities and their accompanying "smartmentality" lead to a modulative form of "surveillance and social control". Iveson and Maaslen (2019) take a decidedly different approach and claim that while the literature has tended to proclaim that modulation has replaced other forms of control (especially in cities), it is more the case that "modulatory forms of social control have not replaced disciplinary forms; [rather,] they co-exist" (Iveson & Maaslen 2019, p. 332). They argue that the crucial site of new social control in cities is actually "powers of 're-assembly' and individualisation" (Iveson & Maaslen 2019, p. 332), rather than surveillance or other forms of power-over. Similar to the usual reading of Foucault, this extended application of Deleuze can invigorate how we read social phenomena as producing new social forms, such as the dividual or the protocological network.

However, this kind of critique can also corner social scientific readings into denouncements of particular technologies for their complicity in these new modes of power. As Deleuze writes, “There is no need to ask which is the toughest or most tolerable regime, for it’s within each of them that liberating and enslaving forces confront one another… There is no need to fear or hope” (Deleuze 1992, p. 4). Resistance is no longer a means of escaping one confined space for another, because there are no more confined spaces. When we look at the Internet of Things as a mechanism of the control society, subjective agency is immediately posed as the possibility of freedom. Attaining that possibility is often posed as a matter of reappropriating the technology — “There’s no reason that your personal ‘Internet of Things’ shouldn’t be a collection of gadgets and apps that you control, not some company off in the cloud somewhere” (Finley 2015) — or devising a critique of the structures of power that control our potential. In both cases, the idea of the subject and its ability to be controlled is taken as an absolute feature of modern technological society.

Even when this issue is more playfully explored, as by experimental “locative media” art, the Internet of Things is again recast as a tool that amplifies modes of subjective control. Locative media uses digital mapping services and devices to either annotate or phenomenologically generate a geolocation experience with the goal of reaching “a mass audience by attempting to engage consumer technologies and redirect their power" (Tuters & Varnellis 2006, pp. 359, 362). Tuters and Varnellis see the Internet of Things as especially important for locative media artists seeking to find new ways to engage with an immanent "society of ubiquitous networked objects" (Tuters & Varnellis 2006, p. 362). A series of human and computer-generated visualizations annotating the production of cheese from udder to supermarket (Milkproject 2006), an algorithmically-generated walking tour of a city (Transmediale 2004), or a tarot-reading service divined from constellations of GPS satellites rather than stars (Leorke & Wood 2019), for example, experiment with freedom of movement, consumerism, and spirituality by intertwining human and computational way-making to create a new understanding of space, movement, and direction. Yet a number of locative art projects — which rely on military-developed telecom infrastructures like GPS and which engage passively in state-enabled citizen surveillance — have been criticised for not adequately engaging with the political ramifications of locative media, unwittingly or perhaps negligently producing an "avant-garde of the society of control" (Tuters & Varnellis 2006, p. 360). Tuters and Varnellis ultimately figure locative media as a "conceptual framework" to examine "technological assemblages" like the IoT and their "potential social impacts", which would culminate in an "awareness of the genealogy of an object as it is embedded in the matrix of its production" (Tuters & Varnellis 2006, p. 362). Thus the usefulness of the Internet of Things is relegated to discerning a mode of production. Any of the IoT's own novelty, in terms of production or otherwise, is ignored for fear of reproducing the power relations of that very mode.

I am suggesting that it might be useful to resist this absolutism, especially when thinking about control. Massumi writes in *Parables for the Virtual* that:

> The current capitalist mode of power could be called control: neither coding nor codification, neither regularization nor regulation, but the immanently encompassing modulation of both. … Control is modulation made a power factor. It is a powering-up — or a powering-away — of potential. The ultimate capture, not of the elements of expression, not even of expression, but of the movement of the event itself (Massumi 2002, p. 88).

To understand and respond to the ways that contemporary networked technologies collude with new capitalist powers, then, means attending to how the "movement of the event itself" might be captured and put to particular ends. At this point it is useful to turn to Lazzaratto, an Italian critical theorist writing today, majorly inspired by Deleuze's collaborations with Felix Guattari. Lazzarato suggests that the principal terrain on which capitalism operates today is at the level of the production of subjectivities (Lazzarato 1996). Where the early stages of capitalism, famously described in Marx's political economic writings, were concerned with the production of objects, today's political economy is a kind of subjective economy. Through capitalism, we are assigned an individual identity — an identity, a sex, a profession, a nationality and so on. We become entrepreneurs of the self, of our own human capital. At the same time, however, we are subject to less humanising processes, which produce us as component parts in a machinic assemblage (Lazzaratto 1996). At this level we exist not as individuals but as 'dividuals' — as data, bits of intelligence, quanta of affect. The dividual has been often used to extend the critique that new modes of digital capitalism are ultimately dehumanizing. Yet Lazzarato's account of contemporary capitalism rejects the notion that there could be a kind of authentic or fully human individuality that lies outside the scene, and which might serve as our point of freedom. Rather, the task is to find ways, within the conditions that produce us, to produce new discourse, new knowledge, and new politics. In order to do this it is necessary to experiment with new ways of speaking, acting, thinking and being, which may not be immediately recognisable, precisely because they are novel.

The literature I have chosen to survey in this section is selective and speculative; they do not reflect the vast majority of publications on the IoT today, but rather reflect significant trends in the current *thought* of the IoT in the social sciences in the recent past, and very likely into the future. The approaches outlined above are likely to persist in the social scientific literature on the IoT and adjacent technologies because they pose the IoT as a problem in need of a solution. Anti-capitalist literature treats the IoT as a problem of deepening exploitation. Ontologically-driven literature treats the IoT as a problem of distancing humans from their worlds and natures. And literature which focuses on the IoT's networking capabilities pose it as a problem of producing new, more resilient butalso more manipulable subjectivities. These are real problems, to be sure. However, they pose the IoT at a fundamental level as a phenomenon that has already been settled, and which can be explained by ideological, economic, or sociological principles that bring it about (platform capitalism; surveillance capitalism; negentropy; the protocol; the network). The technical apparatuses involved in these processes take centre stage, and yet their technical reality is presented as a decided mechanism, gaining liveliness only when human actors intervene, ushering in a new set of social structures and mechanisms seemingly without being inflected by this sociality itself. Furthermore, the processuality of these apparati are prone to being presented as a mode of power claimed by this or that ideology, or as an area of technology which is being increasingly used andexploited by interested powers for either monetary or political gains. This approach requires more nuance, especially if we are to attend to the specificities of hyper-local systems like the Internet of Things and the ways it participates in all manner of social and technical operations, capitalism included.

2.3 What is the problematic?

Thus far I have discussed how the Internet of Things addresses the world through its functioning, and how it has so far been critically addressed. Clearly, it invokes extensive concerns around a number of aspects of contemporary life. With some few exceptions, the critique of the Internet of Things in existing literature is concerned with the ways in which material reality is usurped into ideological paradigms, especially in ways that pose the IoT and its effects as a problem that needs solving. In informational and surveillance capitalism, the Internet of Things is a handmaiden to the interests of big data platforms. In sensor technologies, the Internet of Things bypasses human sense on behalf of ideological sense. And in a society of control, the Internet of Things tightens the coils of the control ideologies. For these critiques to gain any level of potency, they ultimately have to buy into ontologies that obscure the genesis of technical objects. Considering that Internet of Things systems not only have their own singular genesis, but also make claims on the genesis of other objects, this obscurity is a critical blind spot in social scientific engagements with the IoT and, indeed, any such technological systems that integrate the IoT into their operations.

Clearly, though, the Internet of Things is implicated in many existing and future regimes of power. These regimes address contemporary society as a heterogeneous material whole whose multiplicity can be captured by digital practices and tools — the Internet of Things being one of the most crucial tools

— which, as I have shown above, will inevitably be drawn into the homogenizing forces of ideology. It is not my intention to negate ideology as a part of reality. However, beginning with the assumption that ideology is not only inevitable but also inescapable would inevitably flatten any recounting of a technological system into the bearer of this or that ideology, whose implications are already decided. Furthermore, the approach which begins with a critique of ideology implies that before there was ideology, there was something else — a primordial heterogeneous world unsullied by the homogeneous rule of capitalism, control, surveillance, or any chosen ill. Were we to start from this approach, the Internet of Things could only ever address the presence or absence of a potential reality, like "Is this smart city more or less dystopian and surveillant than the last?" Similarly, if this thesis were to begin with the Internet of Things as a collection of pre-given objects, then my task would be reduced to proclaiming those objects as either good or bad, utopian or dystopian, oppressive or liberating. If this is the role of the social sciences in problematizing the new technologies, then the social sciences have been given the unfortunate burden of being the keeper of the measurements of ideology and oppression. The technical reality of technical ensembles like the Internet of Things would, furthermore, be ignored in favour of broad social forces, or would be reduced to the interests of behind-the-scenes human actors. Neither of these approaches are capable of producing problems and questions about the Internet of Things which can engage with its technological and social operations and its operations and its novelty.

Our question, then, is what method can we use to engage with such novelty? As shallow as a method based purely in rooting out latent ideologies would be, it would be equally shallow to proclaim that the counter solution is to trace the IoT's genesis in its entirety. Tracing the IoT would have its utility, but this would be limited to applying an IoT genesis like a stencil to a given socio-technical event or ensemble. The outcome of such a tool would be akin to what Deleuze and Guattari characterized as the "tree" of thought: "to describe a de facto state, to maintain balance in intersubjective relations, or to explore an unconscious that is already there from the start… It consists of tracing, on the basis of an overcoding structure or supporting axis, something that comes ready-made" (Deleuze & Guattari 2004, p. 13). As Deleuze and Guattari go on to discuss, the issue is not that analytical tools are "ready-made"; the issue is that the principles of the ready-made, the edges of the tracing, are mistaken as the essence of the thing being traced. To trace the Internet of Things would be to mistake Things, the Internet, and the connective "of" as stencils of pre-existing principles, when in fact each element may emerge as singularities in a given event. Attending to such singularities is crucial for understanding the role of new technologies in the world, especially for technologies that claim — as discourse on the IoT does — to capture, understand, and act on such singularities.

This attention to the singular is crucial to my own efforts to adequately grasp the singularity of the Internet of Things as a mode of technical individuation. The increasingly familiar academic engagements with the IoT detailed above are instructive in their concern with capitalism, ontology and power, respectively. For me, however, their grasp of these dimensions of contemporary reality, and especially of their inter-articulation via the IoT, is ultimately inadequate. In seeking a more adequate understanding of the singular processes that the IoT operationalises and the singular events that it has the potential to actualise, it is the work of Simondon that I find most instructive. Simondon's exploration of technical modes of individuation keeps the questions of singularity and technical genesis at the fore. To attend to the process of individuation as Simondon does is to attend to singular processes, insofar as the problem of technical reality is not one that 'resolves' in a solution. To write about the IoT, after Simondon, is to appreciate that this specific technology may not be a 'problem', in the negative sense of that term. That is not to say that it is an entirely positive development, but rather that the question of its value will be better addressed to the extent that we more adequately understand its *problematic* status.

To grasp technology in these terms, Simondon has to first address the frameworks through which it had thus far been grasped. Simondon's project addressed the framework of being set out by hylomorphism and atomism. Both ontologies, rooted in Greek philosophies, posit that the principle of individuation is to be found in its result — that is, the individual — rather than in individuation itself. In atomism, individuation is explained by positing atoms as the basic unit of existence, which individuate differently according to other complex materials and forces which connect atoms in different ways. Hylomorphism similarly posits that an individual can be explained by the imposition of a form on a material — for instance, a brick can be explained by the active shaping of a brick mould onto a lump of clay. In both cases, individuation is a *principle* which is placed *before* the individual, in order to explain its genesis. Under these ontologies, therefore, all actual individuations characterize an already individuated being (Simondon 1992).

This manner of understanding individuals as driven by a "principle" of individuation "conceals a presupposition that must be examined"; namely, that "individuation has a principle" (Simondon 2009a, p. 4). Such a presupposition requires attention and critique, Simondon argues in *The Position of the Problem of Ontogenesis*, because it privileges the individual as *the* site of individuation, to the detriment of the "system of reality in which individuation occurs" (Simondon 2009a, p. 4). Mackenzie, an avid scholar of Simondon's work, recounts this problem as originating in the assumption that technological action is radically separated from critical thought — an assumption that was used and explicated by a suite of critical philosophers who inaugurated the field of technology studies, and whose ideas persist in the common sense technological discourse that end up in government policy and advertising (Mackenzie 2003, p. 5). These approaches conceive of technology "monolithically (rather than as *technologies*)" and argue that its inevitable logic is to synthesize human and technical culture in a way "inimical to cultural life and critical thought" (Mackenzie 2003, p. 6). This "hatred" that has historically guided suspicion of machines is, in Simondon's words, not so much a hatred as a "rejection of a strange or foreign reality" (Simondon 2017, p. 16). This can only be addressed, Simondon pleads, by the further integration of human and machine, such that one discovers "the foreign or strange as human" (Simondon 2017, p. 16, my emphasis). What exactly does this rediscovery of the technical as the human entail? And how would we pursue it without reifying an arbitrary concept of human-ness or technology-ness along the way, and also without deifying either?

Individuation for Simondon, then, is specifically what happens “when heterogeneous realities that exceed the individual undergo a new relation and, in doing so, partially and relatively resolve this heterogeneity through an ongoing transformative event” (Keating 2019, p. 216). Thus, individuation never results in a “whole” individual, but only ever a partial resolution of these heterogeneous forces; the relations which constitute individuals are “framed by the passage from disparateness or incompatibility to relative systemic consistency, as being separates itself into phases or zones of compatibility without thereby ever exhausting its potential, its excess’” (Toscano 2006, p. 140). Mackenzie argues that what Simondon provides in this respect is “a way of theorising and figuring things primarily in terms of relationality, as processes of recontextualisation, and in terms of generativity” (Mackenzie 2003, p. 9). Against the monolithic simplification of technologies as inimical to human life, Simondon’s approach emphasizes the “*metastability* or the openness of contexts to events”, defying the characterization of the technical as overbearing and predisposed towards a guaranteed outcome. Ontogenesis, Simondon’s theory for understanding technology as a relational, generative, and always related to its specific material milieu, is a “style of thinking” that allows “following and participating” in the “individuation of things in a given domain” (Mackenzie 2003, p. 9). Ultimately, Mackenzie argues, Simondon provides a way to transform thinking about technology from a problem that is fundamentally alienating to a method of re- integrating with technology itself, in a way that opens up thinking itself to greater sensitivity to the relationality, generativity, novelty, and indeterminacy of the world.

Novelty and indeterminacy are far from unquestionable ideals, however. Much of the discourse around IoT has been focused on its ability to generate novelty and indeterminacy, as much as it is able to produce reliable results and nullify uncertainty. Malcolm Turnbull, a former Australian communications minister, claimed as much when he opened a convention on the IoT in 2015:

> This is a time for everyone — private sector, public sector to be imaginative. This is a time to do new things and be creative. Leap out of bed ready to embrace the exciting things you can do, the way you can unsettle the established order. This is a time for excitement and imagination. There are no technological limits. The only limits are those we impose on ourselves by restricting our imagination (Turnbull 2015).

As a system which can (to a greater or lesser extent) accurately and objectively capture the material events associated with an individual (a home, a sick body, a cataclysmic event, a forest), the Internet of Things could be presented as a tool for divining the principles which govern the mechanism of any given individual. Furthermore, because individuals can be defined as any arbitrary collection of sense events, then the only limit to the discovery of principles is the limit of the imagination. Through this framework, the claims made about the IoT's potential gain some consistency in popular discourse, often in the dualism of utopia and dystopia. If the IoT can get at — and intervene in — the mechanisms which bring about individuals in the future, then of course there will follow a fear of choosing the wrong future. In this way, the IoT's technical operations are stripped of agency beyond revealing what was already present, and the essential problem of the IoT is posed as the problem of human choice. It is precisely this understanding of individuation, and the positioning of technology as a tool to unveil its principles, that Simondon fiercely and repeatedly rejected.

In this hylomorphic formulation, individuals are placed apart from “the system of reality in which the individuation occurs”, which gives an undue “ontological privilege to the constituted individual” (Simondon 2009b, p. 4). Individuation as reconceptualised by Simondon, and Simondon’s theory of ontogenesis more broadly, therefore stands as a promising theoretical framework for investigating new technological systems and their operations in the world.

What Simondon shares with a swathe of process thinkers today is his insistence that becoming, rather than being, is the operation which deserves more attention from philosophers, sociologists, and technologists alike. His term for the process of becoming is *individuation* — a word which gains its own special meaning in Simondon’s greater work. It is worth quoting Simondon at length, to establish what exactly he is claiming about individuation as a process rather than a principle:

> one cannot, even with the highest rigour, speak of an individual, but only of individuation; one must go back to the activity, the genesis, instead of trying to apprehend the being as entirely made in order to discover the criteria by which one will know whether it is an individual or not. The individual is not a being but an act. [. . .] Individuality is an aspect of generation, can be explained by the genesis of a being, and lies in the perpetuation of this genesis (Simondon 1964, quoted in Barthélémy 2012,p. 213).

Importantly, Simondon does not discount being as a part of individuation; rather, it is merely one aspect of an individual’s becoming. Individuals themselves are only ever instances, localizable in time but otherwise only the ongoing process of individualization. There are a number of key ideas in this passage. First, that individuation brings the individual and its characteristics into being at once; the "modality" of an individual does not pre-exist the individual themselves, as classical theories of hylomorphism (the brick mould) or more contemporary theories of personality might argue. Simondon uses the word "individual" to encompass both living and non-living beings. Individuals are never "given substantially" ahead of time (Sauvagnargues 2016, p. 64).

"Being" does not disappear in Simondon's ontology, but it does change its terms and functions. Being is a solution to the problem of living, a solution to the "disparities of becoming" (Grosz 2012, p. 39). Simondon does not pit being against becoming; rather, both are aspects of individuation. Becoming is not a framework that the being must adhere to; this would amount to a set of pre-existing principles or rules that being has to follow in order to exist. Rather, becoming is a single dimension of the being, a "mode" of being that allows an individual to "resolv[e] an initial incompatibility that was rife with potentials" (Simondon 1992, p. 301). Becoming resolves the problems presented to being, "proceeding through crises" (Simondon 1989, p. 223), producing a not-yet-completed individual at each moment. As Grosz argues, this view of the individual opens up enormous avenues for research and inquiry, provoking a significant reconsideration of "the most basic assumptions about what it is to be a subject in a world of pregiven objects, and in doing so [...] to think in new terms about unresolved problems, problems about the real, about forces, about forms of power, and to open up these problems to new modes of address" (Grosz 2012, p. 55).

My turn to Simondon comes at a time in academia which now regularly references processual philosophy in papers, collections, and debates. A key theoretical event which has enabled this integration of process philosophy is the ontological distinction between 'being' and 'becoming', with a shift towards becoming as the origin of investigations into the individual. Simply, this shift is a recognition that the individuals, ensembles, and environments which make up the world are never actually static, and that attention to their movements can create new opportunities to understand, think, and possibly become-with these entities. This is not to say that theories based on representation have no receptivity to becoming, but that when they encounter it, they tend to treat it as a "monstrous" or "accursed" error requiring "expiation" (Deleuze 1994, p. 29). Process and becoming are methods and ethics of thinking; and because thinking is also a way of becoming in the world (thinking is a physical, social, ontological act), to think differently is to become differently as well. As I have tried to show above, the multitude of technological ensembles that participate in the world today, and the way that world is thought, requires a different understanding of becoming, and a different approach to thinking itself. I have chosen processual theories to pursue this difference, which places this thesis in the widening crossover of Simondonian studies and processual philosophy. Indeed, one of the key contributions of this thesis is to address the Internet of Things as not only capable of illustrating this difference, but as a processual phenomenon that engages in this difference as a matter of routine.

Perhaps unsurprisingly, technology has not been written on nearly as extensively as the living in social scientific or philosophical discourses on processual theory, though this is changing year by year. It is not difficult to understand why; whereas the becoming of the living is vital, internal, and often very visible, the becoming of technology does not yet have an internality, is not 'lively' in the sense of biological indeterminacy, and its visibility is often partial, corralled into marketing demonstrations, showing up its effect on human vessels, but hiding mostly within massive infrastructure and behind boxes and vents. New materialist thinkers like, most famously, Jane Bennett have approached technology according to a vitalism that undoes these obstacles of thought by tuning to the ways in which all materialities are animated by a set of singular forces that change over time, are inflected by their other materialities, and which are both universally present and singularly expressive (see Bennett 2010). However, while productive of a new social scientific paradigm, new materialism is not a train of thought I pursue here. Seeking vitalism has the danger of eclipsing technical forces in favour of humanly-recognizable signs of life (this is not something that Jane Bennett does, but which could easily happen in my discussion here). This is why I have chosen Simondon as my major theoretical inspiration: his work provides a number of ways to think technological ensembles as processual on an ontological level without granting them a humanist notion of life or vitality. His work, alongside other processual theorists, creates an opportunity to become-with technical objects.

Though the turn to Simondon has gained significant momentum in the past two decades, his strong ontological program has been critiqued by the social sciences for its reliance on normative claims. Daniela Voss (2019) argues that Simondon's theories of technological progress are characterized by a naturalism which echoed the biologism of the time, “guided by an intrinsic logic and normativity” that frames technics as “an extension of human organs or life processes”, and thereby glossing over the “real” social processes which actually determine the “so-called genesis” of technology and technical forms (Voss 2019, pp. 280, 284). Though Simondon’s attention to the particularities of social normativity is central to Simondon’s project, as David Scott points out:

> Simondon finds that the technical operation realizes what other functions of a community cannot: a norm for determining what it means to act. It provides an image for what it means to act, which permits us to gain an awareness of our relationship to the world, to ourselves and to others, as a kind of “permanent mediation,” the individual’s striving to exist by the continuous operation of reactivating action, existing as its own norm (Scott 2014, p. 195).

This is more than a wishful formula for more meaningful social interaction. Simondon is claiming that the normative is the ontological condition of technical objects, and that “grasping the specificity of a technical object’s being discloses the intrinsic normativity which it provides for its own genesis.” (Scott 2014, p. 195) In the introduction to *On the Mode of Existence of Technical Objects*, Simondon goes as far as to claim that the plight of the technological object is analogous to the plight of the human slave, and that no less than a reformation of a system of ethics and accompanying metaphysics, as was required (arguably, still required) to bring about the abolition of slavery, is necessary to reintegrate the technological with human culture (Simondon 2017, pp. 15-18). In fact, Simondon explicitly argues that technical objects need to recover their normative role in order to heal the alienation afflicting post-industrial society. Simondon’s work is united by this strong ethics and he goes to great philosophical lengths to pursue it, as demonstrated by his extensive reflections on the role of religion and other psycho-social structures in bringing about the conditions for collective individuation (see Simondon 2017). Barthélémy characterizes this element of Simondon's work as his attempt to reintegrate technics with culture, and human experience with the entirety of living reality. Barthélémy calls this a "difficult humanism", as opposed to the "easy humanisms" that would seek to elevate humanity above technological reality and undo all of Simondon's work (Barthélémy & Iliadis 2015, pp. 107-108). It is an easy humanism which would characterize normativity as either a set of rules for enlightened humans of the future to abide by, or as simply another word for oppression. Normativity for Simondon designates the ability of contemporary informational technologies to "couple" with human life, as a consequence of the connection between human schemas of thought and the functioning of technology itself (Barthélémy 2012, p. 211); it is not a structure of rules or symbols that is used to order society (Barbalet 2006, p. 419).

Nevertheless, Simondon's distinctly humanist ethic could arguably run counter to the posthumanist approach I employ in this thesis. Thus, I will simply say for now that Simondon's strong humanism does not need to be embraced in order to put his ontological claims into play; the following chapters will illustrate this clearly without requiring an extensive debate. Furthermore, considering that the Internet of Things is itself animated by strong claims on the real and its unfolding, it seems appropriate to turn to an ontology which makes equally strong claims regarding such transformations.

For this exploration of the Internet of Things and its role in the world, Simondon and his inheritors provide a set of concepts that will help me think through the IoT as a specific technical object. The social sciences require concepts to think about how heterogeneous reality is brought into communication in technology in a way that does not immediately capture or reduce those realities into a blanket operation of control, nor subject reality to the representational operation of the claim. Importantly here for the social sciences, we can see that a stable entity is *one* of the things produced by technical objects (otherwise we would not be able to interact with that same rusty saw over and over again), but there are many other things produced by technical objects, which become difficult if not impossible to study if we fixate out thinking on the single element of stability (Mackenzie 2004, p. 13). Privacy is one such element which has received much attention in IoT systems, the critique of which can sometimes lead to a conceptual dead-end. A study currently being done by the Queensland University of Technology is assessing the ways in which the Internet of Things can be (and has already been) used as a new tool for domestic violence abusers (QUT 2020). Perpetrators can torment their victims by accessing smart home features to change temperature, lock doors, open windows, and access security cameras. The QUT study broadly calls on IoT developers to develop more rigorous securityfeatures into their products so that they are less vulnerable to hacking, lesseningthe risk that they can be turned against victims.

This critique rightly points towards the ways in which IoT systems need to be more secure. However, a Simondonian approach might argue that such a critique, which would call for the abandonment of a technology based on the possibility of its abuse, is instead a sign of a failure to understand the technical reality of the IoT as a whole. For example, Simondon criticised the historical condemnation of Boeing's airplanes (which, for a time, tended to explode mid-flight) as "a gross mistake … A more precise approach has consisted in studying the behaviour of cells subject to vibrations and constraints of internal suppressions, so as to determine the zones of 'fatigue' in metal" (Simondon 2009a, p. 26). Analogously, abusers using smart apps could be regarded as a site of fatigue in IoT systems; the vulnerability of smart homes to malicious use is made possible by the standardization of privacy practices, which strengthens the applicability of IoT systems but fatigues in the face of criminal intent (i.e. the same dozen admin passwords being used over and over (Winder 2019). The success of the Mirai IoT botnet, which infected more than six hundred thousand nodes (Antonakakis et al 2017), illuminates the fatigue of the privacy standards used for the IoT, as much as it illuminates the energetics of the IoT when it is invoked as a global network. Attempts to mend these zones of fatigue, like the IoT Code of Practice (Commonwealth of Australia 2020), goes some way in addressing the points of tension that produce these weaknesses, calling upon the "cognitive schemas" that produce the IoT as a networked reality (Simondon 2009a). However, the fact that it is voluntary, despite other voluntary codes having already been shown to be ineffective (Department for Digital, Culture, Media & Sport 2020), indicates a failure to integrate these schemas more fully into the operation of the IoT, which Simondon might call a failure of the "industrial deepening of production" (Simondon 2009a, p. 26). It is this mode of approaching technical objects that, Simondon stresses, is our only way of ensuring that technical objects can remain integrated in human life; elsewise, we are doomed to subjugate technical objects — as enablers of abuse, extortion, or misery — in a way that leads to both control and subjugation.

It is with this critique in mind that I will be attending to — and emphasizing — the "technical reality" of the Internet of Things throughout this thesis. The fact that the Internet of Things is a fundamentally networked (or network-able) ensemble also requires attention, and can be addressed by Simondon's emphasis on the *partiality* of individuation, as well as the specific nature of post-industrial technologies. Simondon argues that the individual is a "relative reality", a "certain phase of the whole being in question" (Simondon 2017, p. 300). Individuation highlights the partiality of becoming, especially in relation to the living. It is this sense of being unfinished that some authors have picked up on as being constitutive of IoT systems. "By being networked,", Bunz and Miekle argue, "your [products] are never finished — they are now constantly updated and constantly process data" (Bunz & Miekle 2018, p. 20). The authors argue that this un-finishing leads to agency, because the IoT gains skills — "tracking, speaking, seeing and addressing" — from its specific technicity (Bunz & Miekle 2018, p. 20). Beginning from partiality, but avoiding the question of agency altogether, Simondon instead makes the unique claim that technical objects exist as an ongoing symphony of "modes", that is temporary states of being enabled by the collaboration of different operations: "The [technical] object is not only structure but also regime" (Simondon 2009a, p. 24). Viewing technical objects as modes rather than settled objects was a remarkable idea for Simondon's time, and magnificently prescient for the Internet-enabled devices of today that operate precisely by switching between modes: online, offline, energy-saving, data- uploading, and so on. It is for this reason that I will mainly use the phrase "technical object" rather than "technology" throughout this thesis. Doing so may encourage a mode of thinking about the IoT that is less focused on the use of the IoT as a form of generic technology, and shift to a mode of thinking that is more concerned with its specific technical functions.

Social scientists who refuse to begin with the pre-given create much needed conceptual room in the study of technological ensembles. Jennifer Gabrys's ethnographic analysis of the remote sensing lab in the James Reserve Forest in California, for example, addresses the problem of the pre-given by simply refusing to view it as such (Gabrys 2016a). Gabrys spent months within an ecological field site embedded with an array of sensor networks that recorded various measures, from CO2 levels to soil moisture to animal calls. Instead of focusing solely on what these sensor networks could claim within a scientific paradigm of objective epistemologies and the tedious science versus culture debates which can ensue, Gabrys explored how sensor networks' assemblages of objective, subjective, ecological, and, above all sensuous, processes come together to create *matters of concern* for the scientific and non-human community alike (Gabrys 2016a). Gabrys uses Simondon to show how overused concepts like "climate change" can be rethought through their actual material transformations, such as the distinct growth rates of lichens or the migration path of eels (Gabrys 2018; Gabrys 2019). By "reorient[ing] attention from isolated variables to experiences and relations" (Gabrys 2018 p. 360), Gabrys paves the way for a far more intricate understanding of technical objects and their co-constituted communities. Though Gabrys's work was important to the way in which this thesis evolved, it departs from Gabrys when her concerns turn more specifically towards the question of how “smart” events come to be known, parsed, and politicised within the public sphere, shaping the modes of “digital participation” available to communities (see for example Gabrys 2014; Pritchard, Gabrys & Houston 2018; Gabrys, Westerlacken, Urzedo & Ritts 2022). Although Gabrys is similarly focused on the centrality of process, my own interest lies in investigating the machinations that *precede* the social conditions of digital participation and forms of community and politics. While Gabrys appreciates the importance of investigating such machinations, she does not pursue such an investigation with the depth that this thesis allows. What is important is that Gabrys's Simondonian outlook allows her to sidestep questions like “Is it all really predetermined?” and “How accurate are sensor networks at representing life?”, which inevitably produce unsatisfying answers that, once given, are less and less true as they drift further away from their moment of announcement. Returning to process as the mode of analysis, exploration, and address gives everyone — humans like Gabrys, ecological systems, IoT systems, CO2 levels, birds — the ability to reveal something new without abandoning or being tied to what has come before. Given-ness is no longer a problem for the social sciences because it no longer demands complete acceptance or rejection — the given simply becomes part of the process, and part of the problematic.

The Internet of Things requires a similar treatment. As I have tried to show above, the “problem” of the Internet of Things as it is generally given is not sufficient for an in-depth or contemporary response to the kinds of challenges it poses to life and living. One of its most significant challenges is to the social itself. It challenges what counts as sociality: between whom? Recorded by what technologies? How is it sensed? How is it maintained? How can it be acted upon, and in whose company? The generation of the social as a particular kind of problem is still embroiled in a history which has tended to attach technology to a broad critique of the so-called hard sciences. As a side effect of the social sciences trying to engage with the "hard" sciences, what ends up being explained (and over explained) is science, and not the social. In fact, in order to engage with hard science, the social has been simultaneously contained to "relations" and "constructions", as well as attributed to the omnipresent spectre of "society", dissolving the social into a category of "bare nothingness" (Savransky 2018, p. 214). Marres et al argue that the social has to become a different kind of problem in order for the social sciences to interact with it more generatively, and especially after the battlefield leftovers of the science wars. What this specifically requires is a different conception of what constitutes a problem for the social sciences to explore:

> The nature of the social has been, and still is, widely recognized as a problem, but only to the extent that it poses a problem for thought or knowledge … [They] are not that which a certain mode of thinking or knowing encounters as an obstacle to be overcome, but that which sets thinking, knowing and feeling in motion (Savransky 2018, pp. 213, 215).

What happens, they ask, when the social is approached "not as a rallying flag" nor even "an ontological ground" but as "an open problem to be developed here and there, in the heterogeneous cultivation of a world in process?" (Savransky 2018, p. 215) This is the task of contemporary sociology, they argue. I follow Savransky and reframe the social as "the name for a problem that the world poses to itself, that certain events pose in the futures they create" (Savransky

2018, p. 219). Savransky draws from Deleuze, who argued that endowing problems with a “minimum being” (Deleuze 2004, p. 67) means acknowledging that problems are not just social constructions which are relegated to the realm of knowledge and epistemology, but are in fact “a state of the world, a dimension of the system and even its horizon or its home” (Deleuze 1994, p. 280). This gains a particular purchase in technology studies because it means finding a way to consider technologies without being married to the project of dismantling or undermining scientific dogma. De Beistegui (2010) argues the same, strongly stating that an approach based on ontology must contend with the “hard sciences” because that was the home of ontology for the vast majority of its study, and because the development of the hard sciences provides an important challenge to thought today. Contending with science is not a matter of “ignoring such a challenge”, nor “turning it into the sole measure of thought and an unquestionable paradigm” (de Beistegui 2010, p. 109). Rather, it is a matter of “allowing thought to advance in and through a genuine dialogue with science” (de Beistegui 2010, p. 109). Questioning and critiquing scientific dogma is of course to some extent inevitable when discussing the sociality of a technology or technical system. However, this has tended towards a short-sighted understanding of technology in general, and has had the effect of undermining social scientific efforts towards a better understanding of the nature of the relations between humans and technics. Moving from problem to problematics serves this goal of giving a more nuanced approach to technology from the social scientific point of view.

An approach based on the problematic is also fundamentally non-anthropocentric, which avoids many of the conceptual obstacles facing the social sciences today. As Simondonian scholar Andrew Iliadis argues, Simondon's ontology "allows us to finally put aside the subject-object deadlock and instead consider the human that is present in the technological object, and vice versa, as an ensemble… [T]he point is less about the separation of the human from the technical than it is about the successful interoperability of the ensemble" (Iliadis 2013, p. 18). Though Simondon's concern with human-technological relations has come to mark him as a new and exceptional resource for technology studies, this issue had been explored by many others long before his works were translated into the English Western canon. As Colebrook reflects in her paper *All life is artificial life*, the posthumanism and cyborg theories characterised by Andy Clark, Derrida and Haraway over the past 40 years have long rejected the idea that technologies are external artifice. In reality, she summarizes, "we can only think, recall, anticipate and reflect upon our supposedly singular selves and minds, because of the technologies through which we relate to and experience ourselves" (Colebrook 2019, p. 2). Bodies are already technologies, and thus everything done by humans is a technological extension. In a similar vein, Adrian Mackenzie's book *Transductions* explores the "conditions of intelligibility of technological practices in their specificity" which constitute today's collectives (Mackenzie 2002, p. 2). Mackenzie's ultimate concern is with the way in which human becoming necessitates all manner of technological becomings, and vice versa. A theoretical and methodological approach based on process does not negate or deny the human; it simply does not assume its centrality. Alongside these explicitly technically-inclined posthumanist theorists, I am also inspired by a rich field of postphenomenological research which explicitly reject “the dogmatic tendencies of humanism that fetishise the human as the sole agent of transformation” (Williams et al 2019, p. 638). Against the common critique that posthumanist approaches ignore the human-driven forces that determine technological genesis (Voss 2019), I seek to rethink the human and the technological as more mutually constitutive and more intertwined at the level of individuation than most critiques would have them. In as far as the human and the technological can considered to be separate, I follow Gabrys’s argument that “humans are not to be excised from considerations of technology, but rather to be rethought and reworked through techno-geographical relations” (Gabrys 2019, p. 122).

Framing Simondon in this way, as a thinker especially primed for the investigation of social scientific problems from the perspective of difference, is one of many different ways that recent thinkers have argued for Simondon’s relevance to contemporary problems. Pascal Chabot, for example, has given an account of Simondon that focuses on his potential to be recouped by modern Marxist thinking (Chabot 2012), and Andrea Bardin has rigorously charted Simondon’s ontology onto his political philosophy (Bardin 2015). I have been especially influenced by a few key interpretations and elucidations of Simondon’s work. Specifically I have been inspired by Elizabeth Grosz’s reading of Simondon as a method for rethinking identity as individuation, and the promises this holds for reconceiving feminist critique (Grosz 2012). I was inspired by Andrew Iliadis’s faithful attendance to Simondon’s informational ontology, and the implications of rethinking the technicity of the world on the basis of its tendency towards interoperability (Iliadis 2013). Yuk Hui was similarly helpful in his persistently optimistic readings of a Simondonian ontology in today's world, and for his novel application of ontogenesis in digital milieux (Hui 2016). Finally, Sauvagnargues was critical for thinking through my project on a structural level: her work, especially in *Artmachines*, persuasively argues for the relevance of both Simondon and Deleuze in thinking about the constitution of the world through a process of affirmation rather than negation, difference instead of opposition, and problematics instead of problems (Sauvagnargues 2016). Sauvagnargues defines Simondon's concept of the problematic as "the condition of the emergence of a difference, of a sense" (Sauvagnargues 2016, p. 64). Sauvagnargues clarifies that she means this literally as an "objective sense" and "being". The problematic is not "a provisional state of our knowledge", but a real condition of emergence and of coherence itself (Sauvagnargues 2016, p. 64).

To pursue these real conditions of emergence, I embarked on a series of empirical investigations into the IoT as it is operating today, in Australia and overseas. Ironically, despite its claims to ubiquity, the Internet of Things proved to be an empirically elusive phenomenon. Or perhaps difficult is a better word. Commercial protections around new products, architectures, policies and protocols led my material investigations to a number of dead ends. Over the course of my fieldwork I signed a number of non-disclosure agreements, encountered many hesitations to expand on how something worked, and was regularly refused requests for photographs and sometimes even recordings of interviews. The experience was not so much unpleasant as it was awkward, like spending time with someone protecting a secret while still explaining (and sometimes, advertising) everything around it. This awkwardness was repeated in the initial scoping of this thesis's case studies. Increasingly, humans are coming into contact with IoT-like or IoT-enabled artefacts and systems in their everyday lives. There is an IoT standards working group, all with names and offices and phone numbers. There are week-long conferences three times a year, thousands of workers strong with dozens of concurrent sessions, each making some slight kink or mark in the IoT framework, each hastily knitting together a piece of the IoT tapestry. And yet the IoT is not big. It hides in small boxes on phone poles, unfinished on an office desk somewhere, calling on grand infrastructures but popping up in quiet screen notifications, dribbling water under a tree, clipped to an ear. My case studies contract and expand the IoT unevenly and sometimes in an ungainly way. Perhaps this is in my favour, though, as I believe this is how the IoT will continue to roll out: gauchely closing in on some specks of the world, and haphazardly expanding others.

Elucidating the current technical genesis of the IoT entailed an understanding of its development in the technical literature. The field of IoT research in engineering, communications, and general science is truly overwhelming. To delimit my scope, and to ensure I was drawing from reputable sources, I refer mainly to texts published by the IEEE as a source of authoritative English-language information, with the view that none of them present "the" understanding of the IoT. It should be emphasised, however, that an enormous amount of IoT research is happening in many other institutions, and in China and India especially. Unfortunately, it is outside the scope of this thesis to comment on the exciting developments happening there. Considering the current political climate around new ICT systems — for example, banning Huawei from the national Australian 5G infrastructure (Slezak & Bogle 2018) — this partitioning of technical knowledge by language and culture is significant. I have taken this into consideration and, as a response to this problem, have built this thesis mainly around Australian case studies. Considering this local context, the influence of the private sector on the development of public assets in Australia is a significant undertone to the case studies presented here. Technical standards, which guide large and small businesses and organisations alike, are always requested or initiated by corporations. Most if not all publicly available white papers and technical guides on the IoT — both in Australia and internationally — have been commissioned by lobby or interest groups working on behalf of either government bodies (less common) or private industry (more common). This means that publicly available texts on the IoT need to be viewed with a critical eye and with the commercial influence in mind.

It is also important to note that the engineers who write these papers may themselves think along processual and material lines that would open up to Simondon's concepts and a broader rethinking of the IoT's socio-technical reality. However, the way in which the IoT is routinely described is inevitably reductionist, aligning to broader political and philosophical paradigms that are more concerned with the IoT's technical dimensions in a way that establishes its feasibility (and therefore its investment risk) rather than explores the nuances of its operations. Thus, I will be drawing examples from the technical literature, and refer to them regularly for definitions and precision, but my engagement with them is concerned principally to direct them towards a processual consideration.

My approach to interviews with IoT engineers, designers, carers, and practitioners was also to draw out the processual reality of the IoT as they experienced, invented, and nurtured it. I went into each interview with a semi-structured set of questions, but each encounter transformed into an open — and often, energetic — discussion about the IoT in general and their system in particular. Selecting my interviewees was a pragmatic process. There was only one strict condition: they had to be involved with an IoT system currently, soon to be, or previously working. I prioritised people currently working on, involved in, or in charge of an IoT system in Australia, the UK or EU. In the end, I conducted 14 interviews with local and international figures and organisations who were involved in various aspects of the IoT: in specific IoT projects, in producing a regulatory framework for the IoT, in IoT-enabled programs, in IoT art, and so on. I could not gain consistent access to a single project/installation at the beginning of my project (and even as time went on, access was still hesitantly given). My interviews make no claim to be representative of the reality of “the IoT” as such, but function as windows into small IoT-oriented worlds.

In Australia, I targeted case studies through the list of government funded projects under the Smart Cities and Suburbs program. Interviewees who were not working directly on a funded program were recruited through snowball sampling. I interviewed consultants, committee members of smart city councils, engineers, architects, and a farmer. My respondents were overwhelmingly male, usually Caucasian professionals in their middle ages. This is a reflection of the ongoing inhospitality of the profession to women (as documented by Broussard 2018 and many others), and though I was always on the lookout for women to speak to, no opportunity readily presented itself. In fact, the only time I was able to speak to women in the field was during a meeting I sat in on between two major Australian ICT organisations — after which I was asked to sign a Non-Disclosure Agreement. Speaking to interviewees who were not Caucasian was less difficult but, significantly, the majority of these respondents were students. Thus, it is important to see the case studies presented here as necessarily from a demographically normative point of view, despite the quite varied responses I received from my participants. Investigating the identity politics of the IoT would be a rich research question, but is not one I pursue here.

Choosing which parts of my fieldwork to explore in this thesis was an intricate task. In total, I conducted 14 interviews with 18 individuals and performed participant observation at four sites. Each encounter with these IoT spaces resulted in rich interview transcripts and field notes. Deciding which interviews would be selected for my empirical chapters was largely an iterative process. I wrote my theoretical and empirical chapters concurrently, developing my argument and looking to my fieldwork in parallel to ensure that both elements were informed by the other. I was anxious that my empirical data, and my analysis of it, represented a genuine contribution to the field rather than merely a supplement to, or illustration of, a more fundamental theoretical argument. I was also interested in applying Simondon's core ideas to the process of writing itself. Namely, Simondon's critique of hylomorphism entails a view of matter as a positive and active force with its own powers of individuation, and not an inert substance waiting to be moulded. In this same vein, I was keen to allow my fieldwork data to individuate into the body of the thesis; that is, to not start with a theoretical 'mould' into which I pressed the empirical 'clay'. This is not to say that there was no intentionality to my selection process or to my writing; only seven of the 14 interviews were fleshed out into case studies, each of which is characterised by a distinct theme. Rather, my methodological concern was to write in such a way that the empirical data stood up, as it were, as active material in its own right; hence its organisation into 'claims' that are interspersed throughout the thesis, with an eye to drawing attention to the claims that the material makes upon life and thought.

In their literature review on the IoT, Roblek, Mesko and Krapez identify four major fields of IoT research and development: smart infrastructure, health care, supply chains/logistics, and security and privacy (Roblek, Mesko & Krapez 2016, p. 5). The digital health sector is being intensively and fruitfully studied by many STS and body studies scholars (Henwood & Marent 2019; Sanders 2017), supply chain and logistics has enjoyed much attention from critical economical and human geography fields (Ng et al 2014; Birtchnell & Bohme 2020), and security and privacy continues to receive much attention from an expanding collection of academics, activists, citizens, and organisations alike (van Kranenburg & Bassi 2012; Ustek-Spilda et al 2019; Atlam & Wills 2020). My empirical discussion falls almost entirely into the remaining category: smart infrastructure. "Infrastructure" in my case studies included buildings, farms, forests, and community installations. Pursuing smart infrastructure was less of a choice than a product of circumstance and access, as determined by my snowball sampling and the availability of contacts through the Smart Cities and Suburbs grant website. Yet these points of entry proved to be rich areas of investigation, resulting in hours- long interviews and meaningful encounters with an array of environments in Australia and abroad.

One of the major claims I sustain throughout the thesis is that the Internet of Things is characterized by three operations: communicating, sensing, and actuating. Clearly, these operations are far from exhaustive of the many operations which could occur within a given IoT system. And more importantly, while I have chosen to look at each of these operations separately, they often and unavoidably mix and cross into each other's domains, each one making the other possible in some way. Separating them is in a very real sense incorrect, and not at all in line with the technical reality of the Internet of Things. However, examining these three operations separately allows me to explore their significance in the context of social scientific thinking, which tends to perform exactly this kind of separation of technological ensembles into conceptual boxes. My distinctions, while technologically false, are aimed at creating the IoT as a problematic distinctly for the social sciences, and in accordance with my concerns regarding the mobilization of potential. In spite of the dangers of such a move, I will show that a processual approach can open up technological ensembles to social scientific thinking in new and productive ways.

Each theoretical chapter contains three steps. First, I consider a technical operation (communication, sensing, actuation) and the way in which the claim operates through them (connectivity, intelligibility, value). I then turn to Simondon and Deleuze to open up the technical reality of these operations (disparation, associated milieu, the virtual/actual), where "the claim" does not necessarily have purchase yet. Finally, to explain how the claim operates through this new technical reality we have established, I introduce an additional concept (modulation, concretization, transduction) to explain how the Internet of Things' claims subsist in reality while still participating in the transformations inherent in individuation. The empirical chapters, which I have called "Claims", are structured differently. Each Claim examines two or three fieldwork encounters, moving between participant observation, quotes from my respondents, and discussion and analysis. I do not systematically apply the concepts from the preceding theoretical chapters to my case studies. Instead, my aim is to open up each case study from a broad processual lens.

Finally and quickly, a note on terms. Until a term has been specifically addressed, it should be taken as it is popularly used. For example: the Internet, the web, and online, are all synonymous. Internet of Things and IoT are synonymous, though they will be used in different circumstances. "IoT" will be used when it is functioning as an adjective — for example, "IoT sensing", "IoT system" — and "Internet of Things" will be used in all other instances. Distinguishing the parts of an IoT system will become important later, but an initial clarification is useful: I use the phrase "IoT device" to refer to an individual self-reliant component of a larger system (e.g. a sensor apparatus, encased in a protective box). IoT devices are made up of "elements", or components that *do something* but are not self- reliant (e.g. a sensor, a switch, an antenna). I use the phrase "IoT system" to designate a collection of self-reliant IoT devices that are maintained, to some degree, by humans (e.g. engineers, users, etc.) and computational regimes (e.g. cloud data storage and processing servers).

To close this chapter, I will repeat the formula I presented in the first chapter: *The Internet of Things claims to record life in such a way that can be acted upon.* This formula expresses the Internet of Things' operations systematically. "Internet of Things" is a loose term signifying a bundle of characteristics, of which only a few are absolutely necessary: a way to communicate, a way to sense, and a way to actuate. The three operations are mapped onto the phrase like so: "such a way" is the operation of communication; "record life" is the operation of sensing; and "acted upon" is the operation of actuation. Of course these operations can sometimes happen sequentially, sometimes out of order, and usually simultaneously; they are not linear. My aim in creating a formula for the Internet of Things is not to encapsulate all its possibilities into a single phrase. Rather, my aim is to create a concept that conveys the problem presented by an IoT system, and to open up that problem to the problematic. This will always necessitate the production of representations but will never be reducible to them.

3
Communication as Modulation

The Internet of Things claims to record life in such a way that can be acted upon. Such is the formula for the Internet of Thing's operational claim with which I opened this thesis. This chapter unpacks the problem of "such a way". To the extent that the Internet of Things makes a claim upon reality, in what manner does it do this? In asking this question it should be recalled that I am not merely seeking to dispute the claims commonly made about the Internet of Things, but to offer a more adequate understanding of the claims it makes upon the world. Utopian and dystopian engagements with the Internet of Things habitually succumb to the representational error of distributing judgements according to the division between the true and the false; is it true that this represents a progressive technological intervention, or does such a claim mask its more sinister operations? Yet this pretension to be merely reflecting on the given obscures at another, more fundamental, level, for as Deleuze points out, representation is always already a pretension or claim upon reality. In the spirit of this critique, my engagement in this chapter with this question of the manner in which the IoT intervenes in the processuality of the world seeks to mobilize what Deleuze calls the "power of the false"; namely, the power of that claimant that does not pretend to represent the given but rather to produce the genetic.

What we will discover in this chapter is that the operation of communication invokes the power of the false in the way in which it produces, rather than attempts to represent, the technical relation between disparate individuals. Under the hand of the representational, the technical connection between the otherwise-unconnectable has been claimed by the likes of cybernetics and its discursive offspring, which would pose informational homogeneity as the solution to incompatibility. What this amounts to, however, is a hylomorphic account of form and matter: the problems presented by the material world, the qualities of its expressions, are to be reaped by a form (information) in order to establish communication and connect the otherwise unconnectable. This process is posed as a given capacity of communication technologies, and critiques of the social, economic, and technological control which eventuates from this process tend not to engage with the fundamental claim regarding the relation between form and matter that makes such modes of control possible. The remainder of this chapter will engage with precisely this claim.

As discussed in Chapter 2, communication is one of the key technical processes that characterizes a given Internet of Things system. IoT communication is animated by the claim to come into communication with heterogeneous objects by transforming such objects into information. By making the world communicable, the logic goes, that world can be opened up to human intervention, participation, and use. The way in which the Internet of Things feeds existing infrastructures of communication, and the political powers tied up within these infrastructures, means that the Internet of Things' technical genesis has a significant stake in the way the world can be conceptualised and interacted with in years to come. However, if the connectivity enabled by the Internet of Things is simply seen as adding a layer of communication on top of material reality, then the operation of connectivity can never be meaningfully explored outside of scientific discourse. The purpose of this chapter is thus to reconsider the operation of "communication" in IoT systems along more processual lines, specifically with the help of Simondon. The Internet of Things' communicative operations which emphasize the transformation of material reality into abstract data, which can claim to represent that reality, have been extensively covered by the postmodern critique of the sciences — most notably Donna Haraway's informatics of domination (Haraway 2006). What is less theorized, however, is how the Internet of Things also participates in communicative operations which do more than re-represent an existing world, but also actively in-form that world. If, as I have suggested, the transformations brought about by the Internet of Things are not fundamentally representational, then by what operations do they take place?

Communication is what gives us the basis of the Internet of Things' technical relation, both to itself and to the worlds it may inhabit. That relation is expressed as connectivity, and is the basis of the Internet of Things' claims to various kinds of control. Opening up the concept of control - and thereby opening up the technical relation as well - requires investigating the operation of communication more closely. Firstly, a processual framework opens up communication and the basis of its connective capacities as firstly based in difference, rather than similarity. This can be seen, for example, through the problem of standardization in IoT systems, which results not in an increased homogeneity but an increased heterogeneity of modes of connectivity. Secondly, a processual approach would argue that because the origin of communication is difference, then the technical relation is not stable but metastable, meaning that the relation is not pre- determined nor over-coded by the classical notion of information and is in fact involved in a continuous process of in-formation. Thirdly, given these new understandings of connectivity, it may be useful to consider communication as an operation of modulation. Modulation is the operation of "continuous and temporal moulding" that expresses a reciprocal assumption of form between disparate systems.

In this chapter, I will examine more closely this claim that communication and connectivity happen on the basis of similarity, and question the established social scientific critique that equates this similarity to a scenario of total control. For reasons previously discussed, it makes sense that technical practitioners would understand connectivity as a relation based in similarity, and this understanding grounds the paradigm within which the instrumental potentials of the Internet of Things are realised. However, as I have also been arguing, this assumption that connection happens through similarity is one that cannot hold up to a processual approach, which is based on the notion that difference, not similarity, is the basis of the relation. When Keith Ansell-Pearson wrote about Deleuze as a "difference engineer" in 1997, he heralded Deleuze's overturning of Platonism and his enduring preoccupation with wresting, from the margins of representationalism, an ontology capable of grasping the power of differential relations to engineer worlds. Given the contribution that Simondon makes to understanding technology's role in the production of novelty through difference, the latter part of the chapter will draw on his work to produce a more adequate understanding of the communicative operations of the Internet of Things. Understood from a processual approach, communication is less a connection between that which is similar than a modulation of relations that are essentially differential in nature. Before advancing this argument more fully, however, it is necessary to return to the problem of communication and connectivity to outline the operations of the Internet of Things on which technical practitioners understandably focus. It is from this point that we might make visible those more processual and differential operations that are obscured by the focus on connection as a function of similarity.

Section 3.1 first discusses IoT communication as a problem that is distinguished by its claim to extensive and instrumental connectivity, and particularly the claim to bring together realms and individuals which would otherwise be ontologically disparate. In both a technical and cultural sense, this claim is inherited from the long legacy of cybernetics. The cybernetic equivalence of communication and control has also come to characterize social scientific engagements with the Internet of Things. I suggest that cybernetics has over-determined the operation of communication, figuring it as a function that can only affect the world by first transforming it into a representation; which is to say, into information. Section 3.2 will challenge this communication/control paradigm by introducing Gilbert Simondon's theory of individuation as a system based on metastable relations. This theory posits that communication connects two disparate realms into a co-constitutive tension, out of which an individual is produced as a temporary solution to an incompatibility. It is only by this act of disparation that heterogeneous systems can come into communication. Information, rather than a representation of the difference between states, is an active disparation between these different systems. As a result, the individualization of a given system is fundamentally metastable, open to successive disparations insofar as it does not exhaust its preindividual potentials in the production of the individual. Section 3.3 will then discuss how the tension between communication and the metastable individual appears in IoT systems' claims to "smartness". These claims straddle the classic communication/control paradigm, as well as Simondon's informational ontology. I argue that the best concept to make sense of this tension between the classic communication/control paradigm and an informational ontology is Simondon's concept of "modulation". Modulation is the operation that maintains consistency within an individual as it undergoes the acts of disparation and instability that mark individuative processes. Viewed through the concept of modulation, the so-called smartness of an IoT system need not be read as an increasingly nuanced method of control, but rather as an ongoing process of modulation. Communication is thus robbed of its bond to a representational metaphysics and opened up as a technical process based in transformation and difference.

3.1 Connectivity

In the previous chapter I outlined the ways in which the Internet of Things has thus far been problematized, both directly and indirectly via new communication technologies. Clearly, communication itself is a complex problematic, which occupies many interdisciplinary and social scientific fields of study enquiring into what exactly communication means, what it brings into the world, and how it can be understood as a socio-technical operation. In this chapter I will be focusing on one particular aspect of communication that, in the Internet of Things, rhetorically and practically supports the claim to bring about a mass transformation of social life; namely, connectivity. If the things of the world are to be identified, tracked, enlivened and made to speak, then there must be a way to adequately speak back to that world of things and the claim to extensive and instrumental connectivity that is said to distinguish IoT communication. By virtue of this claim, its proponents see the Internet of Things as a technology that will “revolutionize and connect the global world via heterogeneous smart devices through seamless connectivity” (Akpakwu et al 2017, p. 3619). As discussed in Chapter 2, significant communications architectures like the 5G telecommunications network have been built to support this connectivity, and have been developed to accommodate the number of connected objects as well as the vast variety of those objects. The 5G network, for instance, enables both mass distribution and an increasing depth of connectivity, meaning that it can utilize low, medium and high frequency bandwidths to connect singular nodes or devices, major telecom exchanges, and the billions of uniquely identifiable “things” that trail behind them (ACMA 2016).

Significantly, this foundational claim that the Internet of Things makes upon the seemingly immanent connectability of reality itself grounds a proliferation of discursive claims made on behalf of technological connectivity. We could think here of cultural and techno-scientific evocations of the "Internet of Everything" (Miraz et al 2015) or political images of the "Internet of People" (Conti, Passarella & Das 2017) and the "Internet of Citizens" (Crowley, Curry & Breslin 2013) and diverse other claims through which connectivity transcends technical imperatives to produce novel forms of political, cultural and social life. Thus the Internet of Things makes a claim upon the world in terms of its immanent connectability, though it is not a merely passive realisation of already inherent potentials that is at issue here. It would be more accurate to say that the Internet of Things produces the world as connectable, in part because it brings together realms and individuals which — from a representational perspective at least — would otherwise be ontologically distinct and thus separate.

A fitting example is the "Internet of Bio-Nano Things" (IoBNT), a hypothetical proposal of an IoT system which could identify micro communications within a body, communicate these communications to an external data processing system (a cloud, for example), and then instigate an action based on this data. According to its champions, IoBNTs would "host electronic devices and highly miniaturized bio-sensors", allowing them to "eavesdrop" on the infectious bacteria, picking up on their molecule exchanges to determine whether and where abnormal bacterial growth is occurring within a body. These molecular signals would then be "transformed into electrical signals, measured and converted into raw data relayed through the coil/antenna to the wearable hub", which then sends on the data to the web, “where it is processed and delivered to interested parties such as healthcare institutes and emergency services, and [will] send an actuator information if required” (Akyildiz et al 2020). A nurse could be warned of a patient’s sudden decline, an alternate medication could be dispensed, or a state organisation alerted that a new virus is spreading throughout a community.

The authors describe the IoBNT as “a paradigm-shifting concept for communication and network engineering” because it can efficiently transfer information from the “biochemical domain” to the “electrical domain of the Internet through a bio-cyber interface” (Akyildiz et al 2020, p. 140512). The proposal speaks directly to the problems of technical and biological communication that Covid-19 has so vividly brought to the fore. IoBNT would be especially useful in a pandemic or epidemic scenario, it is argued, because its communication relays “are already integrated with mobile devices and remote data analytics tools; IoBNT can be easily configured for tracking, tracing, and quarantining people” (Akyildiz et al 2020, p. 140513). The IoBNT proposes a suite of technological solutions to the problem of recognizing, communicating, and acting upon phenomena which would otherwise be difficult to detect and even harder to action in a timely way. What makes these solutions possible is the mode of communication enabled by the computing paradigm of the Internet of Things; specifically, the ability to transform material biological phenomena (molecules) into material electrical phenomena (digital signals), which can then be taken up by an entirely different system of phenomenal exchange (the Internet, a smartphone notification to quarantine, a patch on the arm, a vaccine). Taken together, these transformations provide the basis for the IoBNT's claim to be a "revolution in the biomedical sciences" (Akyildiz et al 2020, p. 140521) and they constitute a quality of connectivity that has come to typify the Internet of Things more generally.

It is significant that existing technical literature on the Internet of Things emphasises the orientation of communication engineering to preserving the heterogeneity of distinct domains — the locations that a fruit bat travels through (Toledo et al 2018), the weather conditions experienced by a piece of machinery (Oksanen, Linkolehto & Seilonen 2016), the frequencies and durations of vibrations experienced by a construction worker (Meng & Zhu 2020) — to the extent that such heterogeneity can be reliably utilized and reproduced. Given this insistence on the heterogeneity of the domains the IoT connects, it is tempting to assume that connectivity itself is founded upon technical homogeneity — a universal set of communication standards, for example. This assumption is what, from a critical perspective, places the Internet of Things among those forms of communication engineering, networks and digital connection with serious implications for social control. The fears and hopes attached to this form of control, discussed in Chapter 2, are founded on an understanding of communication, and the connectivity it enables, as fundamentally representational. To connect the heterogeneous, the assumption goes, that reality must first be represented to the technology in question, so that it may be relayed as information.

Yet I have been suggesting that this framing of the operations of the Internet of Things and the understanding of power with which it is habitually associated produce an inadequate understanding of both those operations and the mode of power with which it is associated. As suggested in Chapter 2, a more adequate, more processual, grasp of the Internet of Things challenges the self-evidence of the dominant, representational image of the world as constituted of distinct identities, which are only subsequently brought into relation via human activity and technical means. As we will see, in the genesis of IoT communication, this understanding of connectivity as requiring homogeneity is questionable at best. When we look at the technical conditions of IoT connectivity, we will find that heterogeneity is far from nullified, especially at the ontological level. The question for us at the end of this section will be: what theoretical framework can account for the heterogeneity of IoT communication as its ontological condition, rather than as an error or risk to be quashed?

In pursuing this question it is necessary, in the first instance, to question the common reduction of the problem of communication to connectivity. From a broader perspective, it may even seem retrogressive to begin with connectivity as the key to understanding the operation of communication. On this, Guido Stephan, now the Head of Networks and Communication at Siemens Engineering in Munich, said the following to me in a 2015 interview:

> Communication answers three questions. First one is: can you hear me? This is connectivity. Can you understand me? Second question is are we talking the same language? … And then, would you like to agree to what Isaid? This is, in the technical world, a common functionality. New technologies give an

answer to all these 3 questions, where old ones have only answered connectivity.

Connectivity, in Guido's reckoning, is only the first and most basic step in modern communication ensembles, which today involve much more complex and sophisticated operations of translation and agreement. Guido is not wrong; modern information communication technologies (ICTs) at all levels — from a smartphone to a radio tower network to the enormous server farms which power the Internet — integrate higher numbers of operations at much greater speeds, distances, and levels of efficiency as time goes on. This capacity to transmit information faster, smarter and more reliably is indeed at the heart of notions of technological progress in communication technologies.

While the Internet of Things certainly utilises and exploits these advancements in ICTs to maximise its capacity to connect different objects to each other, the Internet and the user (Marcon et al 2017), the idea that its fundamental feature is connectivity is misleading on certain fronts. In this respect, I would agree with Guido that connectivity is only one operation amongst others that are equally crucial. Yet, beyond this, and more fundamentally, it is the understanding of connectivity that the dominant account reproduces that I wish to examine more closely. My point is not to say that connectivity is unimportant, but that the reductivist understanding of connectivity that operates within a representational framing of the Internet of Things oversimplifies its technical operations and, subsequently, assessments of its implications for broader social life.

For instance, the question of connectivity is characteristically described as a problem of compatibility; wrangling large sets of heterogeneous objects or devices within a system means dealing with "very different capabilities from the computational and communication standpoints" (Miorandi et al 2012, p. 1499). From this point of view, a central goal of connectivity is to make otherwise incompatible objects or systems interoperable, since a lack of "true interoperability and interconnectivity between application areas" can exclude a system from being considered a valid IoT system (Bassi & Lange 2013, p. 13). This ability to connect objects that were heretofore un-connected or un-connectable is a significant selling point for IoT companies that promise to deliver value in the form of smart environments, where the connectivity of its parts is the basis for the claim to understand that environment in new ways, usually in the service of greater efficiency or value extraction. This assumes, however, that things are first given as separate individuals that are made connectable via technical means. Yet, as indicated in Chapter 2, my turn to Simondon is motivated by the need to explain the genesis of such individuals and to account for the constitutive role of technology in this genesis. My concern, at this point, is the conclusions that are drawn from the notion that reality consists of essentially discrete objects, which a technology such as the Internet of Things claims to bring into connection. Because of course the Internet of Things does not just operate within the discrete world of technological developments and technical protocols, but also within a political and economic context that contributes to the seeming necessity of its mode of development.

A clear example in this case is the centrality of technical standards in IoT development. Technical Standards are "published documents that establish specifications and procedures designed to ensure the reliability of the materials, products, methods, and/or services people use every day" (ETSI 2016, p.16). Standardization, especially in communications engineering, is "key to achieving universally accepted specifications and protocols for true interoperability between devices and applications" (ETSI 2020). Standardization is thus widely regarded as crucial to the Internet of Things' core function of creating communication between otherwise non-communicable objects. Yet, despite the clear necessity for standardization in IoT systems, demonstrated exhaustively by hundreds of papers promoting or proposing novel protocols for the Internet of Things, as of mid 2021 IEEE P2413 is the only international set of standards for IoT communication architecture, governing the connection of the human and non-human things (devices, servers, continents, users) within its remit. This contraction of protocols into a single standard is indicative of the complexities involved in the process of standardization, which involves the competing interests and investment of commercial parties, the intervention of regulatory bodies and the requirement of extensive evaluation of competing protocols on technical, conceptual and financial grounds.

To say that these political-economic concerns demonstrate the material problems with which the Internet of Things is embroiled only partly gets to the materialist dimensions of the Internet of Things' technical operations, as I argue below. For the moment, I would stress that while the role played by standardization in the political economic functioning of the Internet of Things is indisputable, the technical reality of standardization itself — a haphazard, political, economic, and materially uneven affair — has a processual character that this focus on the governance of individual entities and their connections obscures. A closer examination of some of the more common methods of ensuring connectivity through standardization is instructive here, indicating the greater complexity of the Internet of Things as a techno-social operation and the extent to which the material reality of the technical ensemble bears upon such operations. We could think here of the development of the Internet of Things out of pre-existing protocols and standards for machine-to-machine (M2M) communication, described in Chapter 2. IoT systems emerged when M2M protocols were amended or added to align with other protocols that made communication with the Internet and other objects possible; RFID, LoRaWAN, Bluetooth, and Zigbee are some of the more popular examples (Al-Sarawi et al 2017). These protocols are tried, tested, proven and disproven in fundamentally material circumstances. Wifi may work in an enclosed smart home that needs little signal reach, but is significantly unreliable in smart car parks. RFID is useful for connecting objects that move past physical checkpoints, but has severely limited use if nothing crosses their path. Additionally, IoT systems have their own material requirements and constraints, in the form of "performance requirements" and "energy efficiency" needs — meaning, essentially, the speed of their hard drives and the size of their batteries (Granell et al 2020, p. 403). Beyond the materiality of finance, then, the technical operations of the Internet of Things vary according to the differential material realities captured by the umbrella term, 'mass connectivity.' The varying reliability of Wifi across smart homes and carparks is poorly understood in terms of the constraints upon the functioning of 'the technology itself,' though this is where a more representational account of the Internet of Things leads us. Rather, such considerations draw attention to the more fundamental materiality of the problematic that is the 'Internet of Things' and the constitutive indeterminacy of the domains in which its technical operations unfold.

To take another example, the development of the blockchain protocol has developed with materiality in mind. Increasingly used in IoT communication architecture, blockchain establishes material connections between the actors involved in a digital process or transaction (be they people, organisations, devices, or objects) as a form of trust that certifies a connection. Blockchain is extensive encryption which allows "matter as diverse as persons and persons, persons and things, as well as things and things" to access each other via a 'chain' of encrypted 'blocks' of data (Kall 2018, p. 135). Importantly, each of these blocks are permanently written, which allows the chain of agreements to be visible and unalterable. Each series of blocks produce 'locked connections'; meaning that data about the actors involved are permanently written into the chain of connections, and used to verify future actions and bind the actors to the terms of their original promise. Blockchain protocols are the basis of transformation towards smart infrastructures as a whole: "We may soon see an increasing number of layers of digitalization put on 'physical assets' in order to make them both increasingly traceable and more tangible than they ever were without digital layers" (Kall 2018, p. 135). What is important here, and contrary to familiar narratives around the liquidation of material reality (Berman 1981), the relation between digital communication networks and human needs actually finds a solution in increased materialization.

As a final but far from exhaustive example, the development of IoT networks towards an increasingly modular structure signals both the specification and integration of technical objects' material capacities into operations of communication and connectivity. A common consequence of ICT systems becoming increasingly complex and interactive is an increase in modularity. Broadly, modularity signifies the "independence within and independence across modules" (Baldwin & Clark 2000, p. 63). Modular units are "structurally independent, but work together" (Baldwin & Clark 2000, p. 63); they are externally adaptable at the cost of being much less adaptable internally. This trade-off is associated with more successful communication and performance within a communication network because the various layers of communication protocols — of which there may be many — can interact far more quickly, and with greater energy and computational efficiency (Yelamarthi, Aman, & Abdelgawad 2017). One of my interviewees described his IoT system in praise of its modularity, emphasizing that each module is constrained as much as it is freed by its optimized functions:

> [*handles device*] I can pop that thing off, that communication device right there, I can remove it and replace it with LoRaWan. I can remove it and replace it with Bluetooth. I can remove it and replace it with wifi. I don't care. Each one of those comes with a different set of constraints... It's optimized for what it's trying to solve (interview with David Keightley, November 2018).

In developing towards a more connect-able system of humans, devices, communication networks, matter, and energy, modularity plays an essential role of connecting and communicating between disparate systems and elements via materiality. Standardization, blockchain, and modularization are just a few indications of the increasingly material and processual nature of IoT communication and its subsequent connectivity. The purpose of these examples is to introduce connectivity as a different kind of problematic than more traditional framings would suppose, and to show how the technical reality of communication can be easily obscured when it is portrayed primarily as an issue of increasing control.

Asking ontological questions is important in order to question the assumption that increasing control results from extensive communicative systems and their founding on an increasing homogenisation of such technical, and consequently social, systems. Even champions of the Internet of Things are cognizant of the risks of increasing connectivity, as far as security and privacy are concerned. Some fear that “individuals can be followed without them even knowing about it and would leave their data or at least traces thereof in cyberspace”, a problem exacerbated by the fact that “private actors such as marketing enterprises”, as well as the State, are interested in such data (Weber 2010, p. 24). While some see these problems as challenges for law and policy (see Beale & Berris 2018), others hold a more totalising view of the negative impacts of the IoT and its alignment with dominant forms of power. Phillip Howard, for instance, argues that the Internet of Things creates a “new world order”, which he calls pax technica: “As with the Pax Romana, the Pax Britannia, and the Pax Americana, the pax technica is not about peace. Instead, it is about the stability and predictability of political machinations that comes from having such extensively networked devices” (Howard 2015, p. xx). Such an order requires tight bindings between industries and governments, in the form of “mutual defense pacts, design collaborations, standards setting, and data mining" (Howard 2015, p. xx). Such critiques should not come as much of a surprise, nor should their implicit reliance on the idea that communication technologies ultimately homogenize social reality. And yet, as I have shown with some brief examples above, connectivity is at once a mode of similarity (all speaking the same language) that requires increased disparity (protocols, modularity). Thus, given the ways in which IoT communication and connectivity is based in and produces heterogeneity, where does this homogenizing function come from?

I argue that the social problematic of the Internet of Things is inherited at least in part from the legacy of cybernetics and the classical mathematical theories of information, which continue to inflect discussions about the equivalence of communication technologies with methods of social and physical control. While engineers today would rarely speak in cybernetic terms, the Internet of Things itself is inconceivable without cybernetics, and the communication architectures it has since inspired. Cybernetics is old, at least as old as 1948, when the godfather cybernetician Norbert Wiener defined communication itself as equivalent to control (Wiener 1989). Older still, cybernetics appeared in the 1830s French term *cybernetique*, which calls upon the Greek word *kubernesis*, meaning the act of piloting a vessel. Wiener coined "cybernetics" to designate a new flush of interdisciplinary study into the problem of sensing, processing, and directing human-machine behaviour. In 1953, Karl Deutsch, an American social scientist, wrote *The Nerves of Government* to imagine how cybernetics — as the regulated flow of information and action feedback — might be seriously applied to governing. Between 1971 and 1973, President Allende in Chile installed

Project Cybersyn, a futuristic control room from which Allende could track and manage information about his country in (almost) real time. From 1977 until his death, Foucault developed his theory of governmentality and the ways cybernetic managerialism has become a mode and method of subjectivity (LaFontaine 2007). There is today a thriving communities of scholars in systems thinking and other feedback-based information science fields, and cybernetics' connection between living and non-living systems is today being explored with more philosophical nuance by a number of thinkers (see Halpern 2014; Hui 2019; Malabou 2019; Galloway forthcoming). While this work is being done, it is the more classical concepts of cybernetics that I am interested in pursuing here, especially as it arises in popular discourse. In sum, I take 'cybernetics' very broadly here both as a literal academic discourse — begun in the 1930s and still going today in various journals and conferences, composed of fundamental precepts of communication structure and logic — and as an epistemological legacy that has influenced the way in which communication itself (in technical, biological, and social systems) is understood as a particular, seemingly unavoidable, method of efficiency and control.

The full ramifications of cybernetics on social life has been exhaustively explored by a number of scholars. Here, I am focusing on how the technical assumptions of cybernetics — that is, its reliance on the mathematical theory of information — has encouraged a reading of communication technologies as ultimately controlling. Firstly, as a technical paradigm, cybernetics is classically characterized by two major functions — feedback and self-regulation — which are geared towards capturing environmental and internal change in such a way that can provoke further change. Wiener defined feedback as "the property of being able to adjust future conduct by past performance" (Weiner 1989, p. 33). A predefined process receives information about its surroundings over time, which allows the process to change itself according to the information it receives, and in line with its arbitrary goals. An action taken by the system generates a change in the environment, either internal or external, and that change is reflected back into the system. For example, a given human body has a desired body temperature equilibrium. Reaching and maintaining that temperature is a matter of continuous communication between the body's organs and nervous system, which respond to the internal and external environment and make appropriate changes. Self-regulation follows this continuous communication as the ability to regulate these changes within certain parameters to ensure the systems' continual functioning. In contemporary technical literature, a system's ability to maintain itself despite self-inflicted and external changes brought on by feedback is referred to as "robustness". The development of the Internet instigated an enormous increase in concerns about, and methods for ensuring robust and resilient communication network feedback operations (Sterbenz et al 2010). For this control to be most effective, then, there needs to be a constant and high-fidelity system of communication in place.

Secondly, then, to support the technical operations of feedback and self-regulation, the cybernetic paradigm requires a theory of information that enables a stable system of communication. This has come to be known as the mathematical theory of communication (MTC), and includes Claude Shannon's theory, as well as the work by Wiener, Weaver, Osgood and Schramm that closely followed (Iliadis 2013, p. 6). Defining the "fundamental problem of communication" as "reproducing at one point either exactly or approximately a message selected at another point" (Shannon 1948, p. 379), the original proponents of MTC took the view that semantics was itself its own problem that could not be solved by the reproduction of messages (Shannon 1948, p. 380), and therefore focused instead on the reliable transmission of probability values (Weaver 1953). By relying on an understanding of information as a measurement of the degree of uncertainty contained in a signal (Shannon 1949; Wiener 1950), MTC generated a working theory of communication with the instrumental view of reducing uncertainty to its smallest degree.

Though there is no short supply of theories of information (at least 32, according to Rocchi & Resca 2018), cybernetics and MTC have been persistent cultural shorthand for the equivalence of communication systems with encroaching systems of social and political control. And it is no wonder that this is the case, considering the clarity and instrumentality of the cybernetic theory and use of information. If information is constituted by the difference between states (a 0 or 1), then the content of information itself is irrelevant to the functioning of the system. As long as there is a way to differentiate between a finite set of states, as either absolutes or degrees, then that difference can be communicated. If you can then communicate that difference over time, the system can be given an arbitrary goal to work towards. An IoT system, for example, could be attached to mental health patients' bodies in order to sense when a manic or depressive event might be starting — marked by a quantitative change in state of the pituitary gland, heart rate, or digestion — and then to deploy an appropriate response: a suicide watch team, an injection, closing the blinds, turning up the music, and so on. Over time, profiles could be built around these collected data, and pre-emptive actions taken long before (or even shortly before) a predicted event. In the same way that potential terrorists are identified and tracked by their online activities, particular patterns of sensation could be recognised, attached to individuals or sensed across a space or time, for punitive or policy measures alike. In a more likely scenario, these profiles could be used as stand- ins for citizen engagement (see Botsman 2017), and are already being employed as the basis for accessing cheaper insurance schemes (see Laustsen, Gregersen, & Jakobsen 2016). Predictive algorithms for determining "risk profiles" for crime in a city have been available and operational since 2015 (Shapiro 2019).

With an IoT system integrated into such immanent risk assessment tools, profiling individuals, regions, times of day, weather patterns, and events would appear self-evident and complete in its immanence. The late Mark Fisher, for instance, proposed that modern systems of communication — which he argued are cybernetic in nature — pose a system of power in which control is no longer centralised, but immanent to communication systems themselves:

> The study of feedback is immediately a study of control and communication; control is distinguished from domination, since it is immanent to the system — the machine corrects itself — and this self-correcting function depends upon communication (the efficient processing of information about what is happening both "inside" the system and "outside" it) (Fisher 2018, p. 22).

Due to the constant connectivity of different systems, Fisher argues, feedback is operationalised through an anticipatory system of deviation. Feedback mechanisms are able to discern normal and abnormal states — either as a result of an original parameter, or as something learned — which is used to bring the system back "in line", whatever that may look like. Mackenzie Wark, drawing from Fisher and Maurizio Lazzarato, extends the implications of such an immanent system of social control into the sphere of labour and language. She argues that cybernetics and the mathematical theory of information creates a language that is purely "functional" and "devoid of meaning", which is able to mobilize "new kinds of flexible subjects" needed by neo-capitalism (Wark 2017, p. 87). The combination of feedback, self-regulation, systems thinking, and uncertainty reduction provide a powerful logic by which to organise not just systems, but the very relationship between humans and anticipatory technologies.

If the cybernetic approach to communication is taken at face value, then a transformation of the world into a homogeneous realm of information waiting to be extracted and put to work by the technical ensemble is clearly inevitable. Connectivity can lead, and has already led, to novel forms of control which can directly support contemporary modes of power, especially under certain profiteering strategies. I do not want to downplay these encroaching modes of power, but I also do not want to accept the terms under which these arguments about power are often made — namely that this control follows from a classically cybernetic understanding of IoT systems as capturing something purely instrumental. Instead, I want to address the control individuated by the

Internet of Things as one which is an operation of difference. Ultimately, the control wielded by cybernetics is fundamentally based in its capacity to transform a system — a material and immaterial ensemble — into information, which is then subjected to a regime of manipulation by the cybernetic system itself as well as the humans who have designed it. Similarly, the increasing modularity and protocols necessitated by the expansion of IoT systems indicates the transformation of the world and the vast technical networks and structures that enable it. From this perspective, the relation between communication (as the least-indeterminate transmission of information possible) and control develops out of the strong determination of difference. The jump from this understanding of communication into the more worrisome or dystopian possibilities is, as shown above, not very difficult, and certainly something that needs continued attention in the coming years.

But what has become lost in this problematization of communication? Precisely the characteristics of the Internet of Things that, as I showed above, are driving its genesis. We have already had a glimpse of how something more than control can be discovered if we take standardization and modularity as the basis of our investigation, rather than as evidence of a pre-existing cause. The question now is how exactly to pursue and, as it were, co-individuate with the operation of communication. Rather than dismiss cybernetics wholesale for construing this transformation as primarily oriented towards control, it may be useful instead to ask: what of these transformations? How might the transformations introduced by the operations of communication be explored? As I will explore in the following section, Simondon's concept of disparation is crucial in following this line of questioning, and arriving at a problematic that is worthy of the operation of communication.

Undoing the relationship between information, communication, and control requires a different understanding of the ontology of technical objects, a different understanding of information, and a revaluation of the concept of difference. The next section will turn to Simondon's theory of ontogenesis, which poses a way to rethink the operation of communication as one that looks to the quality of information as a productive tension, rather than an understanding of information as representative and quantitative. As Iliadis says, "Simondon approached information from a perspective that allowed for the interoperability of different types of information, leaving space for indeterminacy that would remain a fundamental component of Simondon's open informational schema" (Iliadis 2013, p. 5). Simondon's concept of disparation will be shown to be the basis of connection and communication between heterogeneous objects. Integrating indeterminacy and tension into his ontology actually allows for a more nuanced understanding of power, which we will discuss in 3.3.

3.2 Disparation

The previous section discussed the fact that communication is commonly presented as a problem of connectivity, and considered the implications of a technological ensemble that can spread, maintain and instrumentalize that connectivity as a mode of control. Though classical cybernetics may have fallen somewhat out of fashion and is not often cited in contemporary publications on the Internet of Things, the connection between communication and control remains strong in technical and social scientific fields alike. This reading of communication and the broader significance of connectivity can generate productive readings of the Internet of Things — especially regarding corporate use of private data, for example — but the operation of communication itself is neglected somewhat. Or rather, it can be portrayed as a technically complex but socially straightforward process of connectivity. For example, the mathematical theory of communication introduces the idea that different individuals need a system of similarity in order to function — they need to speak the same language, as Guido says. By asserting similarity as the basis of the connective relation, the mathematical theory of communication introduces another idea: that 'things' are fundamentally *incompatible*, and can only come into relation with the help of *similarity* and *identity*. The implication for engineers is that they inherit a representational mode of thinking which poses incompatibility as a *problem* which can only be *a* with technical intervention and its identifying operations.

My issue with this representational approach (typified by the mathematical theory of communication) is not its *technical accuracy* from an engineering standpoint. Clearly, the communication systems and protocols based in the retrieval of statistical probabilities in the form of light and/or electricity are real and functional. However, this understanding of communication, and implicitly the notion of information that follows it, can lead — and often does — to a scenario where the technical operation of communication is posed as a particular kind of social problem, which holds to a reductive view of the technical reality of the Internet of Things. What concerns me is that the representationalist account of communication and connectivity offers an impoverished view of these operations. Here, Simondon is indispensable in his insistence that it is not similarity but *disparity* that allows "things" to come into communication. And nowhere can evidence of this be found more than in the genesis of technical objects as a process of *in-formation*. In this section I will develop a counter-reading of information that shows how an initial difference, rather than similarity, is at the heart of communication. In order to do so, I draw on Simondon's theory of "disparation" as a way of understanding the operation through which essentially heterogeneous levels of reality communicate.

The dominant theory of information, with its origins in MTC and its reductive understanding of communication as connectivity, functions as a response to the problem of how essentially distinct entities come into relation. The underpinning assumption of this problem is that individuals come into relation as pre-made entities. If this is the case, then the concept of information — as a representation of the state of affairs of an individual at a particular place and time — makes sense. However, this initial assumption prevents any understanding of individuation as an ongoing process. This was a primary concern for Simondon, who saw this philosophical prejudice towards the presumption of given-ness as an obstacle to thinking about the relation between humans and technical objects as anything other than the meeting of two irreconcilable realities (Simondon 2017, pp. 15-17). To counter this tendency of thought, Simondon developed one of his more lasting and well-cited arguments: his critique of the hylomorphic and atomistic ontological schemas. To demonstrate the inadequacies of these two classic (but persistent) ontologies, he poses a now-classic example of the meeting of a brick mould and a lump of clay. According to a hylomorphic or atomistic reading, a brick emerges after the clay material has been shaped by the imposing form of the mould. Clay and mould both have set characteristics, the foremost being the passivity of the matter and the activity of the mould in producing the individualized brick. By this ontological logic, individuals are always the result of various "forms" that "mould" them at various instances throughout their existence (Simondon 2017, pp. 249-250; Simondon 2009b, pp. 4-5).

Simondon argues that these schemas, based in the presumption that an individual can be explained according to a pre-existing principle of individuation, is to blame for many errors of thought regarding the ontological relation between humans and technical objects, be they as complex as the Internet or as simple as a brick. It is not the imposition of form over a passive material that makes the brick, Simondon argues, but rather a reciprocal assumption of form between the clay and the mould (Simondon 2017, p. 249). The brick and the mould have some predetermined characteristics (e.g. clay made from limestone sand has a set density; the concrete mould produces a brick of 20 centimetres long) but their co-individuation is not wholly determined by these characteristics. The mould resists the specific strength of the clay (in-formed by its composition of variously-sized grit and its viscosity), and the clay resists the bounds of the mould (in-formed by the material of the mould, its shapes and points of weakness). As Sauvagnargues puts it:

> Each molecule of the clay *enters into communication* with the pressure exercised by the surface of the mould, in constant communication with the geometric form concretised in the mould; the mould is as informed bythe clay as the clay is by the mould, having to resist, to a certain point [...]the constraints that it exercises on the mould (Sauvagnargues 2016, p. 70,my emphasis).

In-formation thus gives us an initial glimpse into how we can start to rethink communication as a material operation not entirely determined by its quantitative characteristics. With a reciprocal notion of information as a process of *in-forming*, already we have a more productive, specific, and technical way of thinking the operation of communication as much more than the transmission of uncertainty values.

Uncertainty, however, does not disappear in his formula for communication. Simondon notes the crucial tension in communication engineering, namely "an informational efficiency sufficient for practical needs" as well as "an energetic efficiency that is sufficiently high to keep background noise" to a minimum (Simondon 2017, p. 147). Resolving this tension is not, Simondon argues, a matter of abolishing all uncertainty during transmission. On the contrary, in order for information to emerge from communication, there must be both a regulating form (for example, a radio tuned into a particular frequency) that provides a ground for the incoming transmission, as well as a “margin of indeterminacy” that allows information to be distinguished by the regulating ground (Simondon 2017, p. 150). If an information signal were entirely predictable, there would simply be no signal to transmit. Information thus belongs to an order that “brings about a series of unpredictable, new states, not belonging to any series that could be defined in advance” (Simondon 2017, p. 150). While other accounts of information, like the MTC, might not immediately take issue with this proposition, the implications of this formula for understanding technical objects leads to an entirely different reading. For instance, the potential individuations of “calculating machines” (the direct ancestors to modern computers) do not lie in their specific coding, but rather in their “primitive margin of indeterminacy” that allows the machine to do otherwise; the ability of a computer to “extract cube roots” as well as “translate a simple text, composed of a small number of words and expressions, from one language into another” cannot *originate* in its programming logic, but must instead originate from the margin of indeterminacy that enables such information to arise (Simondon 2017, p. 18). Thus, while a technical object requires the ability to determine information according to a set of pre-given forms, it is its margin of indeterminacy that informs its relationality (Simondon 2017, p. 157).

If certainty (in binary code, or uncertainty values, or other such forms) is not the origin of information but rather one of its consequences, then an ontological frame more attuned to this constitutive indeterminacy is crucial. To this end, Simondon's refiguring of information as a processual operation is significant, as it takes incompatibility as its ontological ground. Developing the notion that information becomes possible at the point at which sender and receiver might diverge (rather than at the point at which they meet, as in MTC) Simondon then argued that information is "never relative to a unique and homogeneous reality, but to two different orders that are in a state of disparation" (Simondon 2009b, p. 9). Immediately the contrast with MTC is significant: whereas MTC relies on a concept of information as a "thing" to be communicated, and thereby determined to some extent in advance, Simondon's approach instead posits that information must processually arise from "the *relationship* between source and receiver" (Simondon 2007, cited by Iliadis 2013, p. 10). Disparation is the concept he invents to describe this relational process of in-forming.

Simondon borrows the analogy of disparation from perception studies, which describes it as the production of depth from two incompatible images. Binocular vision, for example, produces 3D vision from the "irreducible disparity" of the images generated by the left and right eyes (Sauvagnargues 2012, p. 6). Rather than leading to a state of confusion, the incompatibility of the eyes is the basis for the "creative solution" of vision. Even when vision is interrupted (as with a missing eye) or confounded (as with crossed eyes, or macular degeneration), there is still a creative solution; a single eye still takes in light and produces an image, even if it is not binocular, and even when it is clouded by the thinning of the macula. Disparation is thus the process of two heterogeneous realities coming into communication. The creative solution that results from this process is information itself.

Disparation implies a few key things. Firstly, that information cannot be thought of as a given term, as it absolutely relies on the dynamics of the system from which it arises. It cannot be approached as an entity with a pre-given identity or unity, as the MTC or broadly cybernetic approach might do, because information is “not an end; it requires a system” (Simondon 2007, cited by Iliadis 2013, p. 11). In which case, and to paraphrase Simondon’s iconic phrase, the static notion of “form” can be replaced with the process of “in-formation”. Secondly, for information to arise from the communication between two levels of reality, this means that these realities must harbour an initial level of incompatibility that harbour the capacity to come into relation. An antenna, for example, comes into relation with a radio wave as a result of an original difference between the two structures, which is then resolved by the meeting of the magnetic oscillations and the properties of the metal rod that vibrate in response. Thus, information arises from a system that is both stable (as in the capacities of the metal rod and the radio wave) and unstable (as in the indeterminacy of this relation). In other words, information arises from a state of *metastability*.

Drawing on the concept of metastability from physics, Simondon defines metastability as “a state of tension” resulting from an “incompatibility of the system with itself” (Simondon 2017, p. 177). Information, as this relation of incompatibility that finds a solution, is therefore an expression of the compatibility of these heterogeneous systems. Disparation is thus the very "condition of coherence" of a technical ensemble. This is where MTC and Simondon's informational ontology differ most starkly, and yet are not necessarily incompatible. Whereas MTC is concerned with the safe retrieval of the content of a transmission (which is achieved brilliantly today by the many complex global communication infrastructures), Simondon is far more concerned with developing a technique for understanding the *plurality* of communication, and the many different ways in which two systems might come into relation and become interoperable. Disparation, and the fundamental incompatibility and indeterminacy it heralds, is critical to this task. Thus, disparation and the attending concepts of metastability and in-formation offer an alternative understanding of the operation of communication: not as the connection between pre-established forms, but as the very connection of disparate levels of reality via a metastable process of in-formation.

Before we move onto the implications of disparation for the Internet of Things, an important note must be made regarding the state of computation at the time of Simondon's writing. At the height of his writing career, Simondon was experiencing — and getting actively involved in — the very beginnings of modern computing, just a few decades before the invention and proliferation of the Internet. In fact, his work has been read as profoundly prescient, "border[ing] on that of a clairvoyant" (Iliadis 2013, p. 11) regarding its applicability to the Internet itself. However, one might ask whether his understanding of indeterminacy and machines still holds in relation to digital systems. For Yuk Hui, for instance, the question revolves around the status of new "digital objects", which he argues are a new type of technical object for which Simondon's ontology did not (and could not) originally account, the implication being that a new approach is required to explain their nature (Hui 2016). This is a question we will return to again in later chapters, especially concerning the ability of digital systems to produce genuinely novel individuations. At this point, the question of in-formation, disparity, and the digital can be addressed by Simondon's emphasis on in-formation as an *internal* process of individuation more than a series of *external* signals. Simondon addressed these as two separate categories: "One could say that the information is always internal, it should not be confused with information signals and media signals" (Simondon 2007, cited by Iliadis 2013, p. 11). For instance, the disparation of vision in-forms the very structure and genesis of the eye (pupil; optic nerve; retinal vessels; surrounding muscles) as well as what is seen. Likewise, the disparation undertaken by a computer processor in-forms the structure and genesis of its heterogeneous parts (motherboard; solder; capacitors; external casing) as well as what is processed by it. Though admittedly, and as will become important later, the ability of these processes of disparation to persist and continue differs between the living and the non-living. For now, and given my concern is less with digital objects than with complex networks of digital, analog, living and non-living ensembles, a Simondonian approach remains adequate.

Indeed, even for the newest forms of digital computation, Simondon still provides a novel and meaningful interpretation. For example, if we were to take

Simondon's approach to machine learning, we might first say that machine learning is a perfect example of indeterminacy in operation, with respect to the question of sensitivity to outside information. The job of a machine learning algorithm is to take outside information, analyse it according to its internal structures, and change itself according to the dimensions of this new state of affairs. Machine learning is consistent with many of the assertions of cybernetics and MTC in this sense. However, it could be argued that a machine learning algorithm does not demonstrate *sensitivity* to outside information because its *internal operations* are not *transformed* by the information itself (see Klobucar 2020). What we will see in the next section is that machine learning earns a new productive dimension (one that is deeply linked to new modes of power) when the human is seen as an integral and *modulative* element of the technical ensemble.

Furthermore, the increasing materiality of communication systems (which I described earlier in the chapter) can also be grasped through a Simondonian framework. Sauvagnargues extols Simondon's work for being able to convey a theory of signs as a material event: "the theory of the sign is substituted for a theory of physical causality" (Sauvagnargues 2016, p. 65). Similarly, Anna Munster's work on "signaletics" theorizes the study of digital signals as a deeply materialist affair. She argues that code, understood as blocks of signals, does not represent the world through its signalling, as "our experience of contemporary technicity is always in process before the labour of codification" (Munster 2014, p. 151). A whole "network of spatio-temporal relays through which technical objects are diffracted" is encountered and experienced materially before a specific code begins to labour in a given space. Video from a drone, for example, enters into an assemblage of political and affective materialities long before and after the camera recording begins; drone cam footage today is necessarily related to the physical practices of geofencing, privacy laws that influence which faces can be recorded, and the development of anti-drone 'guns' that shoot debilitating nets. It therefore no longer suffices to "count code as the ontological marker for a range of technical phenomena, the generation of a variety of media, or our relations with these. Something else is already in the process, working itself through actual technical objects and their relations" (Munster 2014, p. 151). The 'something else' proposed by Munster is the more processual and unstable animation of signaletics.

Munster defines signal as "fundamentally beyond, before and above the human… Signal is transmitted through relays that are not entirely encoded nor entirely under human control" (Munster 2014, p. 153). In line with Simondon, Munster argues that signal "tends toward instability"; as an "energetic" material, it "persist[s] outside our attempts to encode and decode it", being always in a state of fluctuation (Munster 2014, p. 154). She points to the ways in which signal technologies have been developed to "counter the fluctuating unstable tendencies of signal by various methods of capture" (Munster 2014, p. 155). More than anything, Munster argues, "it is a mistake … to reduce signal's transmission to digitally mediated communication flows", which would gloss over, if not wholly ignore, the way in which "signaletic material both continues to become *and* is stratified by regimes" (Munster 2014, p. 165). Ultimately, she argues that "the work of encoding and decoding, accomplished at the site of signal capture and modulation, cannot be considered as the defining or determining element in the energetic movements of signal" (Munster 2014, p. 165). Instead, an attention to the transmateriality of signal, and the way in which it regularly crosses the thresholds of encoding and decoding, provides an analysis of contemporary media assemblages that is sensitive to its materialities and can accommodate the novel solutions to the problem of signal that may arise.

Signaletics, as one example of a Simondonian approach to information and disparation, highlights the metastability of communication by referring to its inherent and material instabilities. It emphasizes that each communicative event is ontologically based on material energetics rather than the labour of code; that is, on reciprocal and fundamental indeterminacy rather than the re-presentation of a form. In the following section we will see that these metastabilities are necessary for understanding the forms of power that emerge from a more material, heterogeneous, and processual understanding of communication. Ultimately, Simondon characterizes the process of communication and connection between disparate realms as transductive — a key concept that I will return to in Chapter 5, and which explains the way in which the human-technical relation can induce collective transformation. For now, it is enough to say that Simondon's concept of communication, which positions communication in the act of disparation within a metastable field, transforms it into an operation that requires disparity, tension, and heterogeneity as a precursor and condition.

By reframing communication as the operation which is based in and generated by disparity, the technical problem of connectivity raised by the Internet of Things sidesteps the reductive tendencies of "control society" polemics. Of course, this is not to say that the elements of a so-called control society cannot eventuate from a saturation of IoT-like communication networks. But importantly, these elements would not be a product of some ontological condition that renders all life homogeneous and thereby controllable. Rather, with Simondon's concept of disparation, the elements of a control society emerge from an operation of communication which is based in *ongoing disparity*. IoT communication thus becomes thinkable as that which renders metastable transformations of the world visible. At this point we are very far from the initial concerns outlined at the beginning of this chapter. Communication in the classic, cybernetic, and contemporary sense is no longer (for us at least) a problem of control, similarity, or identity. It has transformed from an operation concerned with representation into a problematic by which technical ensembles are generated and, more importantly here, how they are maintained. However, what still needs to be addressed is the way in which IoT communication is connected to its claims. The final section of this chapter will now discuss how the claims made by IoT communication operate via *modulation*.

3.3 Modulation

In light of our new understanding of communication as processual, based in indeterminacy, and arising out of disparation, we can finally return to the issue of control with a different perspective. Control is one of the effects of communication, and it comes about from the relative tightening of the margins of an ensemble's indeterminacy; that is, from modulation. As mentioned in Chapter 2, Simondon's concept of modulation, along with Deleuze's *Societies of Control*, helps to make sense of contemporary forms of power, especially in relation to extensive digital networks and their freedom from the typical enclosures of disciplinary space. In the remainder of this chapter, I argue that modulation is an especially important concept and operation for understanding IoT communication because it appears in the characterization and evolution of IoT ensembles as "smart". The increasing equivalence of smart technology with the Internet of Things is especially noteworthy, and points to a complex relation between power, communication, and modulation. Before I explore "smartness" in relation to IoT systems, I will first establish more precisely what Simondon's concept of modulation entails, and how it speaks to the operation of communication as we have established it.

Modulation in the communication engineering sense deeply influenced Simondon's use of the term, and is based on the key elements of communication that I have discussed thus far. Specifically, modulation is a process of *transforming information* in a way that accounts for its materiality and its indeterminacy. In communication engineering, modulation denotes the way that signal wavelengths can be manipulated to conform to a different shape, usually one more suitable for the transmission and receiver apparatus. Over time, modulation has come to accommodate digital information and its relative virtuality, but without entirely abandoning the materiality of the analog. In analog processes, modulation is the continuous modulation of an electromagnetic wave either by its amplitude or frequency. The information is conveyed by the carrier — for example, by the sound of AM radio (which is modulated according to its amplitude) or FM radio (which is modulated by its frequency). Digital modulation involves a further step. Rather than being present within the carrier signal, the information is first present as a digital bit (0 or 1), converted into an electromagnetic wave, and then "demodulated" back into a digital bit for the receiver. In both analog and digital processes, modulation is the process of controlling these amplitudes and frequencies for a particular effect — for example, to increase the amount of data that can be communicated, to lower power use, or to eliminate noise. In this sense, modulation is the way that an electromagnetic wave is *changed*, *moulded*, or *transformed* in order to communicate its information in a particular way.

This transformation is both bound and enabled by the material constraints and opportunities of the type of modulation protocol used, as well as the constraints and opportunities of the communication system as a whole. In practice, modulation protocols reciprocally determine and are determined by an IoT system's data and physical architecture. In small and simple IoT systems, for example, modulation protocols like Bluetooth, ZigBee, or the cellular/wifi network can transmit large quantities of data in relatively efficient ways, but at a relatively short distance and with high energy usage; as a result, these methods of communication are not often used in commercialised IoT systems. Larger IoT systems are much more likely to use the LPWAN (low power wide area network) modulation protocol, which transmits much smaller volumes of data and is low-power, low-range and low-cost (Mekki 2019, p. 1). Now a well-established part of the modern IoT communication architecture repertoire, LPWAN is regularly cited as a solution for connecting objects that are "smart, autonomous, and heterogeneous" (Mekki et al 2019, p. 1), especially for large-scale smart city and agricultural projects within Australia (SCCANZ 2018; Newcastle City Council 2017; Islam, Ray & Pasnandideh 2020). I will return to this alliance between modulation and smart applications later in this section; in this context, modulation — the ability to change communication protocols according to contextual material specifications — is what technically enables an IoT system to achieve connectivity.

Within the LPWAN protocol there are a number of proprietary models, each designed for specific purposes and with different material constraints and opportunities. SigFox and NBIoT, for example, use narrowband binary and quadrature phase shifting (meaning the wave form either conveys four or eight bits, doubling or quadrupling the usual amount of information carried), whereas LoRa uses a wideband chirp-spread spectrum (meaning a wave form carrying two bits is "chirped" repeatedly within its whole spectrum, drowning out the possibility of noise). These material differences in modulation — to recall, electromagnetic waves are material events — are reciprocally in-formed by the material indeterminacies of the space in which they operate. For example, SigFox and LoRa are especially apt at high-coverage and low battery consumption. This makes them particularly useful for smart agriculture systems, which typically require huge swathes of land to be monitored, functions to be carried out over a long period of time, and a wide array of atmospheric, animal-centric, and extensive logistical data to be communicated, but not frequently, or with the expectation that much has changed. The material transformations of a farm are (at least in some applications) slower than a typical commercial application, and the quality of its connectivity is thus based more on consistency than speed. Thus, while NBIoT provides the highest level of reliable and consistent connectivity, its reliance on the 4G (and in some cases, pre-4G) network and the modulation techniques of cellular communication make it largely useless for the demands of a farm, which in Australia are likely to be excluded from most cellular networks in any case (Mekki et al 2019, pp. 5-6). Significantly different from the connectivity presented at the beginning of this chapter — that is, the connection of pre-existing individuals via the translation of the world into immaterial information — connectivity from the point of view of modulation is already skewed towards reciprocal material transformations.

As I have outlined it so far, modulation from a communication engineering perspective already speaks to an understanding of communication from the point of its technical reality, thereby closing some doors (which would lead to the kind of understanding of IoT communication that we have already established as inadequate) and opening others. To take it further, from a Simondonian perspective, modulation also provides a way to understand the power relations which can emerge from IoT communication. Sauvagnargues compares Simondon's modulation to the more common concept of "moulding". Whereas moulding — like the mould which forms clay into the shape of a brick — is "an abstract conception that opposes matter to form", modulation is "a continuous 'assumption of form' between properties of material and the concrete action of form" (Sauvagnargues 2016, p. 70). Importantly, the concept of modulation does not deny the existence of bricks or of moulding. "Of course, the mould endures after the operation, while the clay is turned into a brick", Sauvagnargues points out, "but what counts is that the frame of the mould and the material modulate, enter into a common system, an associated milieu, and together realise an operation of individuation (the brick; bricking) through a continuous exchange of information" (Sauvagnargues 2016, p. 69). Modulation, therefore, is molding, but "in a continuous and perpetually variable manner" (Simondon 1964, cited by Sauvagnargues 2016, p. 69).

Continuity and perpetual variability are two important aspects of modulation. We can see them in the engineering concept of modulation explained earlier: waveforms are modulated in a continuous and variable way, and the waveforms themselves are perpetually variable. As shown above, the type of modulation chosen (and the type which succeeds) is reciprocally determined by the constraints and enablements of a given milieu. For Simondon, this relationship between continuity and perpetual variability, and the constraints and enablements of a given milieu, are part of the same process. As Yuk Hui explains, modulation for Simondon denotes "a constant becoming according to certain measures and constraints" (Hui 2015, p. 80). The "certain constraints" are not bare-faced obstacles, but rather are what enable individuation to occur. Simondon explains this in terms of amplification:

> One could say that the boundary between the structural germ and the structurable, metastable field is a modulator; it is the energy of metastability of the field, therefore of matter, that allows the structure, therefore the form, to advance: the potentials reside in matter, and the boundary between form and matter is an amplifier relay. (Simondon 2019,p. 573).

Modulation is thus the operation that amplifies the material potentials of a given system of individuation, in order to make those potentialities *available* to the forces of disparation. LPWAN, then, is more than an arbitrary technique for controlling the flow of data across a network; it expresses and generates the potential of that network to come into communication with its milieu.

How does this conception of modulation contribute to our understanding of the Internet of Things as a problematic for the social sciences? It would be easy to re- insert a representational politics here, which would point to the "who" missing from Simondon's equations; who controls the regimes of metastability, who owns the means of in-formation, and so on. But this would miss the manner in which modulation speaks to the ability to generate new milieus via the continuous variation of the realm of potential; that is, how it acts within the margin of indeterminacy. Modulation is the operation that enables us to see this more clearly than a classical understanding of communication would, and leads into more complex concepts of connectivity and transformation in the contemporary world. I am arguing, then, that communication, classically understood, does not generate a problematic that can allow the social sciences to adequately address the technical reality of the Internet of Things. In an IoT system, the mode of communication which actively generates *problems* (rather than just representations) is modulation.

Simondon's theory of individuation and in-formation provides an account of the Internet of Things (and technical objects in general), which helps to undo the short-circuit between communication and control on the level of the technical object, the individual who comes into contact with an IoT system, and the collective understanding of how the Internet of Things' complex communicative structures interact with human life. However, while communication can be unyoked from control, control itself does not disappear in a given Internet of Things system. How, then, do we account for control in the Internet of Things without falling back into cybernetic analogies? Influenced by Deleuze's use of Simondon, I have drawn on the idea of modulation to attend with more nuance to the ways that the Internet of Things intervenes in reality, including though not exclusively, social reality. Deleuze discussed modulation also in terms of control, but in the sense that modulation occurs when individuals are subjected to the continuous impetus to communicate themselves (in the form of information), and to subject that communicability to continuous change (the rhetoric of adaptability or resilience, for example). Control is not so much a matter of using that information itself against the individual, as it is a matter of subjecting individuals to an ongoing force of modulation in the face of new communicative forces.

Modulation as a mode of power is especially clear in the alignment of the Internet of Things with "smart" technologies. Smart applications, and "smartness" in general, has been a technical term for over four decades (Goddard, Kemp & Lane 1997). And yet, what exactly constitutes 'smartness' and 'intelligence' in technical systems is "ill defined and malleable", most often appearing as a corporate marketing term to denote processes that create "consumer satisfaction and work efficiency" but not much else (Halpern 2014, p. 3). Urban, ecological, economic, political and infrastructural viability into the future are now commonly deemed possible only through the intervention of smart systems and processes. Speaking of the public uptake of smart energy meters, Marres (2012, p. 290) explains how devices like solar panels and wind farms are given "special significance" as an example of "how to 'manage' a turbulent world" by bringing the social, the technological, and the environmental "into alignment". Ultimately, it is digital technology that is assigned the privileged role of "what enables this convergence of different forms of change" (Marres 2012, pp. 290-291). Discourse around the Internet of Things has certainly profited from this privilege, making strong and regular claims that IoT systems can perform this management due to its "smartness". In fact, some have claimed that "smartness" itself is "tantamount to the IoT concept" (Severi et al 2014).

At this point the relationship between the Internet of Things, smartness, communication and power is still vague and rests on presuppositions about what each of these operations entail. To undo this bundle of assumptions, I will turn to a single but increasingly common example of "smart objects" in IoT communication architecture. So-called "smart objects" have been called the "building blocks" for IoT systems, because they enable an IoT system to work in arbitrary spaces (Kortuem et al 2010, p. 30). Smart objects' communication architecture is much more complex than the classic 'tag and reader' format of RFID tag systems. Instead, smart objects work around "chunks of application logic", which are small bundles of commands that execute according to inputs and outputs as they arrive, rather than executing at regular points (Kortuem et al 2010, p. 31). It is as a result of "chunking" that smart objects can claim the ability to "sense, log, and interpret what's occurring within themselves and the world", enabling them to "act on their own" and communicate both with humans and each other (Kortuem et al 2010, pp. 30, 36). Smartness in this example is expressed in the way that an IoT system can act in a manner that is *continuously variable according to its environment*. In effect, this means that an IoT system achieves smartness when it engages in *sufficiently complex operations of modulation*. Not only do smart objects require the technical operation of modulation to bring "chunks" into communication (thereby achieving greater awareness of its continuous variability), they also engage in a reciprocal act of amplification and in-formation.

This example raises the greater question of how power operates within these modulatory modes of communication. To this end, Yuk Hui (2015) has proposed a way to reappropriate modulation away from "social techniques of control" — typified by simplistic readings of Deleuze's control society, Galloway's protocological power, and Rouvroy's algorithmic governmentality — and reframe modulation as a particular mode of individuation. He draws attention to what he calls the "modulation-control correlation" (Hui 2015, p. 87). This correlation poses that modulation is likely to lead to social control because it can amplify techniques of social control. For example, a social relation of particular magnitude (e.g. the individual-group relation, as with advertising) can be represented by a data structure and amplified (as in advertising based on algorithmic sorting), which can then be sold or turned for profit (Hui 2015, p. 90). Modulation could therefore be easily read as a digital operation that has been developed to limit individuation to modes which agree with broader ends of profiteering or manipulation. Hui admits that some modes of digital modulation have been turned exactly to this purpose. However, he resists the temptation to abandon modulation as a source of productive critique, arguing that the modulation-control correlation both is based on an understanding of modulatory systems as entirely "motivated by the cybernetic goal of maximum efficiency" (Hui 2015, p. 88), which he argues is a very limited approach to technical systems, and which, as I have shown above, is only a partial aspect of the Internet of Things. Instead, Hui is concerned with understanding modulation not purely as a mode of control, but as a mode of individuation in its own right (Hui 2015, p. 87). In reposing modulation this way, Hui does not seek to eliminate control as a concept, but to "invent new forms of modulation that are not limited to forms of [social control]", or be limited by them (Hui 2015, p. 88). Hui's interpretation of Simondon's theory of modulation paves a way to reconsider modulation as a mode of individuation that, while prone to being exploited by control society techniques, is not inherently based in control or cybernetic concerns.

With Hui's emphasis on individuation in mind, it is now possible to consider that the mode of control that emerges from the individuation of massive communication structures is modulative. Meaning: control does not simply operate as an imposing form on passive matter (whether that matter be forests, or buildings, or people), but as a progressive emergence of a communication between levels of reality. Thus, for example, the alignment of smart cities with ideals of "participatory governance" (ETSI 2015, p. 8) is not just a utopian pipedream or a cynical illusion, but an operation that becomes possible with the kind of power relations that emerge from expansive systems of modulation. This also includes the more cynical outcome of new forms of individualization. Smartness is often framed as creating an ongoing experience which is governable towards a particular outcome — usually happiness, intuition, and efficiency. In this sense, the Internet of Things intervenes in social reality to instigate modulative regimes of in-formation. These are also forms of subjectivation, which modulate the diverse potentials of individuation toward the production of certain kinds of individual, in the name of "smartness" and social utility. This is the reading of Deleuze's *Societies of Control* that makes sense to pursue in a reading of the Internet of Things. Deleuze discussed modulation also in terms of control, but in the sense that modulation occurs when individuals are subjected to the continuous impetus to communicate themselves (in the form of information), and to subject that communicability to continuous change (the rhetoric of adaptability and resilience, for example) (Deleuze 1992). Control in this scenario is not so much a matter of using that collected information against the individual, as it is a matter of subjecting individuals to an ongoing force of modulation in the face of new communicative forces.

Thus, if we reject the image of the Internet of Things as a system that acts upon a given world, and instead see it as a system that actively produces the world as a mode of individuation, then modulation is clearly a more adequate understanding of the Internet of Things' implication in both old and emerging modes of power. If communication is simply power, then there is not much more to say. Social science cannot answer the question of power in the Internet of Things without understanding the technical reality to which power speaks. I am guided by Simondon's ontological argument that individuals are temporary effects, only a mode of existence, rather than the stable reference points on which to base social theory. When individuals are freed from stability, commonly conceptualized as the subject/object dualism, transformation becomes much easier to account for, and to examine for new machinations of power.

In this chapter, we began with communication as a problem usually concerned with the operation of connectivity, and the possibility of extensive connectivity leading to a scenario of homogenizing control — with the Internet of Things being a technology of control *par excellence*. By looking at the increasing modularity, standardization, and materiality of IoT communication, I opened up connectivity from a strict issue of representing the world (as classically posed by cybernetics), to a question regarding the quality of that connection and ongoing communication. In the following section, I turned to Simondon's concept of disparation, and the attending concepts of metastability and in-formation, to establish an understanding of communication as rooted in material metastability. To understand the implications of this for a social scientific view of communication, I finally turned to the concept of modulation, which accounts for the technical reality of IoT communication as an operation which enables new power relations, which are themselves modes of individuation.

Though my discussion has been furnished with a number of examples from the literature, what modulation actually *means* for a social scientist may still be unclear. Andrew Iliadis argues that modulation offers something specific to a social scientific analysis of communication:

> A Simondonian method would seek to proceed by articulating instances of the modulation of communicative processes themselves, rather than in the simple 'transmission' of meaning or data between pre-given, already individuated entities. An individuative methodology would seek to measure, uncover or understand those communicative structures that modulate in the act of communication and that perpetuate by virtue of an individuative flexibility (Iliadis 2013, p. 17, my emphasis).

Claim I, my first empirical chapter, looks at three such instances. It will consider three IoT scenarios: first an encounter with Tom, our dairy farmer, in his workshop; then with two smart city projects, neither of which come to fruition; and finally with a series of boxes, nestled in an engineering lab. Though all projects were funded under the *Smart City* grant program, and all are concerned with the broad goals of increasing efficiency and good decision-making at a commercial and social scale, modulation emerges in these scenarios in completely different ways. Without our re-formed concept of communication, and the attention to disparation, metastability, and materiality that this involves, our reading of these three ensembles would be quite different; perhaps more critical and actionable towards a social good (or some other predetermined end), but also perhaps less attendant to the real forces of transformation at work in each.

Claim I

Smarting cities

“To succeed in the 21st Century economy”, the 2016 Australian government *Smart Cities Plan* begins, “our cities need to be productive and accessible, but they also need to be liveable with a clear focus on serving their citizens” (Commonwealth of Australia 2016). These eminently liveable cities of the future are threatened by the costs of expansion and concentration: “congestion, poor access to jobs and services, reduced housing affordability and increasing pollution can challenge the quality of life [our cities] offer.” The *Plan*, a broad national strategy for directing smart city policy and government funding, offers a long-term reprieve from these problems by promising to support projects that “leverag[e] real-time data” and thereby relieve the strain of congestion, affordability, pollution, and job scarcity by merit of their “smartness”. Soon after the Plan was published, the government released the Smart Cities and Suburbs Program, a grant scheme to fund “innovative smart city projects that improve the liveability, productivity and sustainability of cities and towns across Australia” (Australian Government 2020). Over three years the Program distributed $50 million between 81 projects, ranging from 3D mapping software, to frog population management, to an entire digital infrastructure for a major city. Many of the projects involved IoT systems, though these systems appeared under the general guise of “smart sensors” paired with “digital infrastructures” that use “real-time” and often “open” data to enable “evidence based management" of public assets and produce "informed decisions" (Commonwealth of Australia 2016). Projects funded under the scheme continue to come to fruition, regularly appearing in news articles lauding smart city innovations to "help create the best possible City for our residents, workers, students and visitors for decades to come" (City of Parramatta 2020).

It would be easy, but perhaps also unfair, to read the *Plan* and its subsequent grant scheme as an instance of the kind of superficial efforts to brush the problems of urban living under the smart carpet that Morozov and Bria criticise (2018). Perhaps anticipating such critiques, the *Plan* explicitly describes itself as a broad approach to the "complex" and incredibly "contextual" question of how to live in a city, and more specifically Australian metropolitan and regional cities, which have the unique characteristics of being "highly urbanised since European settlement", housing "more than three quarters of our population", and producing eighty percent of Australia's economic activity (Commonwealth of Australia 2016). There are other noteworthy things about the Plan, especially in light of the implicit and explicit connections it makes between communication technologies and the way it utilizes the concept of "smartness". The first to note is a quote found at the beginning of Chapter Three, entitled "Building the cities of tomorrow". The quote, in bold, reads: "Cities are first and foremost for people. Their function is to serve humanity, so they must have a human form". Following this quote are the three pillars of the Plan: smart infrastructure, smart policy, and smart technology. Its list of "challenges and opportunities" includes the economy, jobs, housing, transport, green urban space, and human capital. To live up to its promise to build the cities of tomorrow, the Plan pays demonstrably less attention to the specific technologies used; the smart technology pillar mentions nothing about any particular devices, and instead is concerned with “thinking”, “leveraging” and “driving” new and old technologies as they become available or applicable. What this requires is, above all, a level of communicability, whether in the form of smart sensors delivering real-time data about the world or the connectivity between such technical objects and their many stakeholders. Considering the *Plan* and its focus on human liveability in the context of the operation of communication as I have discussed it thus far, it is fair to say that what becomes communicable under the *Plan* is the human form itself; a form that must become even more communicable to retain the liveability of the city in the face of its dangers and breaking points.

As discussed in Chapter 3, the so-called smartness of communication technologies can be understood as an operation of modulation. Smartness lays bare the human-technical relation and presents an opportunity to engage with a system’s indeterminacy, rather than merely a new way to control it. In light of this framing of smartness, and my rethinking of IoT communication as a metastable operation which is operatively modulatory, I will now discuss a project funded under the Smart Cities and Suburbs grant scheme and describe my conversations with the team of student engineers who developed it. The project touches the deep nerve of the promises of smartness in contemporary Australian smart cities in their relative infancy.

Queanbeyan

Our first smart city project is based in Queanbeyan, New South Wales, an "old fashioned town with a high street" (interview with Martin Darcy, from notes, February 2019). It has a population of around 37,000 and it borders the northeast corner of the Australian Capital Territory. Under the grant scheme, Queanbeyan won a $950,000 grant to develop the centre of Queanbeyan as a smart city precinct. Over 3 years, the city developed and installed a suite of internet-connected technological systems, including free wifi, motion-activated street lighting, parking lots with sensors, a 3D digital model of the city, and a series of sensors down a major road (QPRC 2020). Queanbeyan has joined the collection of Australian towns and cities that have developed their own smart precincts, like Perth's Open Data Portal (see https://data.perth.wa.gov.au/), which collects data from 52 IoT LoRaWAN networks across the city. The potential benefits of these systems are often lauded; Hastie (2019) celebrates the way that Perth's nodes turn "everyday objects" into "smarter versions of themselves", and claims that it will encourage students to become more interested in STEM, more businesses to invest in the city, and citizens across the board to "think creatively" and "build solutions" (Hastie 2019).

The most recent element of the Queanbeyan project, which I will discuss here, is a sensor network installed along the main street, through which all the major traffic flows, in a few local parks, and in the Murrumbidgee River that runs perpendicular to the main street. The network is made up of 15 nodes, each of which measure different things depending on their location. The nodes on the Monaro Highway, the high street, measure noise levels. Nodes on light poles throughout the town measure air temperature, UV levels, humidity, and pollen count, and subterranean nodes measure soil temperature. In the river, the nodes measure water temperature, turbidity, conductivity, dissolved oxygen and pollution levels. The sensors transmit the data to an online dashboard, which collates and presents the information gathered. One of the goals of the project is to provide a way for Queanbeyan's citizens to learn about the town before venturing out for the day. Knowing the current water temperature and pollution levels could be used to decide whether to go for a swim in the river, and allergy counts or UV levels could be used to decide whether it is safe for children to spend time outside. The developers of the project, Nishant and Arsh, told me that these environmental metrics "should be more than enough for the public to index, you know, what's the quality of the water, is it safe, or is the surrounding impacting some way the goings on of their life" (interview with Nishant and Arsh, February 2019).

Queanbeyan River bend. Image by Author, 2021

Public documents from the Queanbeyan-Palerang Regional Council (QPRC) describe the sensor network project in an expectedly hopeful way, aspiring to deliver "a diverse, resilient and smart economy fostering businesses that create jobs and wealth for all in our community" (QPRC 2018). In my interview with

Martin Darcy, the Service Manager of Business and Innovation for the QPRC, I discovered that the hope attached to the Project comes from a strong sense of Queanbeyan's struggles. Queanbeyan lies on the border of the Australian Capital Territory, about half an hour from the centre of Canberra. Despite its proximity to a bustling economic hub, Queanbeyan sees little of Canberra's wealth. Martin described how over the past few decades life has been sucked out of the retail scene, with Queanbeyan becoming "a drive-through city" and online shopping drawing customers away from its "brick-and-mortar stores" (interview with Martin Darcy, from notes, February 2019). The "economic beast" of the ACT government lies just over the NSW/ACT border, gobbling up Queanbeyan workers, tourists and shoppers from that crucial high street (interview with Martin Darcy, from notes, February 2019). Queanbeyan is smarting — in both senses of the word.

Relieving economic ailments is a common promise of smart city reinvigoration schemes, usually delivered by the rollout of extensive networks which will deliver efficiency gains in saved time and greater value production. Certainly these benefits are of interest to the QPRC. However, after my conversation with Martin, it became clear that for Queanbeyan the promise of smartness is much more a promise for people. When Martin spoke about making the data collected by the system public, he explicitly said that there was little concern around privacy; the focus was on "just working out what's happening", "letting people see", and "making things better". In this context, open data can only realize its potential when it can be shared. Much more pressing for Martin was digital inclusion. The question of whether Queanbeyan residents could afford data plans to access the city's smart initiatives was especially on his mind. More instrumental concerns, like measuring the differences between Queanbeyan's traffic patterns before the construction of a bypass road, and the patterns which would follow after the bypass's completion, would be equally significant for the Council.

Smart light poles; looking up and down the high street. Images by Author, 2021

When I asked Martin how he would define smartness, he responded that it concerns the way that technology is used, rather than any particular technology in itself; specifically, a way that "processes and patterns can be improved to deliver sustainable social and economic outcomes … we are creatures of habit", he mused, and our patterns of habit reveal "how we work". This, he said with some dismay, is the most difficult part of creating and maintaining smart cities. The conversation shifted back, again, to the lack of social structures that would support smartness in its full technical realization. Enormous cultural change is required to implement smart city devices and systems, spanning individual computer literacy skills, organisational resistance to new ICT paradigms, and economic support for consistent and reliable forms of Internet access. While the *Plan* acknowledges these fundamental roadblocks to the rollout of smart cities across Australia, there is little advice to be had regarding how to overcome them. Councils like the QPRC, while receiving significant support, have been given the task of not only introducing smart technologies into their communities, but also of integrating technical activity into human life itself. Smartness, either in Martin's image of an integration of habit and use, or the *Plan*'s notion of the communicable human form, is not yet available in the city of Queanbeyan. In this sense, it is the *lack* of modulation, and the generation of human-technical communicability that would follow, that has motivated and, as Martin offered, thus far characterised Queanbeyan's *Smart Cities* project. In contrast, the following *Smart Cities* funded project generates, and indeed relies on, a veritable excess of modulation, connectivity, and communicability — though to a similarly unfulfilled end.

ACT Housing

ACT Housing, a local government body that manages the distribution of public housing, also received funding under the *Smart Cities* scheme to develop an online portal for public house seekers to view which houses are available for them to occupy, and to be able to choose a place they would like to live in (or at least indicate their preferences). Currently, public housing applicants are placed in homes according to their personal circumstances and needs. As of today, this information — concerning disability status, income, current address, criminal record, number of dependents, and so on — is largely kept physically, and must be resubmitted each time an applicant's circumstances change, or if they need to change their housing arrangements, or if their housing arrangements are changed for them. For applicants, this could mean getting an appointment with a specialist every year to re-certify that they have a lifelong disability. Or it could mean resubmitting personal testimony and police records of traumatic abuse. Under the proposed new website, which will be backed up by an extensive new database, applicants' details will be collected, stored securely, and will be used to determine which houses are available to them and when they are available. Once the new website is built, applicants will not only have all their paperwork digitally on file, but will also be able to peruse houses that are deemed suitable for them based on that paperwork; for example, houses that have wheelchair access ramps, or are located in a different suburb than where an abusive partner lives.

Technically, this project is not strictly IoT-enabled. In fact it has very little to do with smart devices at all; ultimately it is a website development project which takes advantage of new database techniques and tools to deliver a government service more efficiently. However, the project explicitly satisfies one of the Smart Cities three pillars: "We will become smarter investors in our cities' infrastructures" (Department of Infrastructure 2019), which includes housing and particularly "housing affordability". The project falls under the "smart" roadmap, but doesn't involve "smart technology" as such. Despite this lack of directly smart technology, the project still involves the kind of cybernetic governance and impetus for communication discussed throughout Chapter 3, specifically in the way it points to how modulation might produce forms of subjectivation in the context of the political problems of poverty and precarity. As we will see, the proposed website raises issues and questions pertaining to the creeping connectivity of government services and the ends to which this connectivity is put.

I met with Stacey and Phil from ACT Housing about the website redevelopment in 2019, who at the time were the leads on the project. Though ACT Housing has a “significant” portfolio of properties across the Canberra region, they admitted that it had not always been managed in a way that resulted in high housing rates:

> We have about 700 people on the waiting list to move, and they’re going to have to wait years, because we have to balance that need with people who we’re allocating a home for the first time. Typically, if you’re comparing someone who’s housed, although not in our ideal home, compared with someone who’s living in a car, we’re gonna give the person living in a car the option.

Providing housing was their ultimate goal, but in saying so they recognised that housing availability is directly connected to housing management — and, more specifically, information management. As they described it:

> **Stacey**: So what we’re trying to do is build [a platform] that allows people who are already housed to see what properties are coming up, and then to identify preferred properties that they’d be happy to move into, and then to use the technology to actually create chains of movement across the portfolio and then house more people than we currently can with the paper-based process.
> **Phil**: It’s almost like the Allhomes concept.
> **Stacey**: It does a little bit more than the Allhomes concept, but from the client’s perspective, they’ll be able to log in, to see their profile, to see the information we hold about them, opt in opt out of transfers, see property

characteristics, you know, how far a property is from a school.

As straightforward as it might seem to implement an “Allhomes”-like website (a popular Australian real estate portal), Stacey and Phil knew from the start that it would require a series of technical, bureaucratic, labour, and social transformations within ACT Housing, external consultants, advocates, and its ever growing pool of clients. They both spoke at length about the kinds of organisational changes that they were dealing with and trying to instigate, often with little luck. For instance, in 2018, shortly after winning the Smart Cities grant, they were approached by a company to collaborate on their mission to eradicate homelessness in the ACT. At the time, there were about 1800 people on the public housing waiting list and, conveniently, about 1800 empty bedrooms in the ACT Housing portfolio. They realised that by changing how ACT Housing manages and procures properties, alongside the website database’s new way of “moving clients across the portfolio”, they could, hypothetically, fill those bedrooms within the year. Negotiations broke down, however, as the website failed to come to fruition in time, after a series of delays, internal resistance to a change in process, and the sheer difficulty of moving such a large quantity of data across mediums.

Despite these hurdles, Stacey and Phil were confident that the website would satisfy its aims, especially those concerned with increased transparency. More than providing a clear interface through which to manage housing — which is in itself a significant task, and sorely needed (Polillo et al 2021) — the website would also create an opportunity for applicants to actively participate in their housing, and to have a more direct connection with ACT Housing, as Stacey described:

> [The website is] a digital platform that allows our tenants to view the available properties [...] in the public housing portfolio, and to really [...]easily manage the information we hold about that, so they can see that information. They can then decide whether or not to opt into a transferand then nominate a property from the wish list.

Importantly for both Stacey and Phil, the capacity for applicants to participate in the process of housing was an important goal, reflecting one of the project's core values as well as the broader aim of digital transformation and "smartness". Phil described smartness as a process driven by creating value — for clients as well as for ACT Housing:

> I think it's the use of contemporary technology to expose transparency, simplify, build trust, and realize value. I think that's what smart means for us... It is about extracting the inherent value from the information sets we currently have, and it's helping realize those strategic organizational outcomes as well as the benefits [for] the clients.

Stacey agreed with Phil, and elaborated by returning to the problem of information management:

> So I think we've kind of conceived of the term smart as [...] taking the information that we already hold and using that as meaningful data that can then inform decisions. And give increased visibility, so that people know what information we hold, and then they can control what we can and can't see about them. That may impact what they're eligible for, but if people are aware, if people can see that, they can see what impact their decisions have... The other data issue for us is about portfolio managing, so using the

> information [from the platform, which] gives us data on whichhouses are or aren't in demand… What characteristics feature with those properties, to help us inform our decisions around our portfolio.

Of course, submitting their details to the new website would provide public housing recipients some very tangible freedoms: no need to prove with an expensive specialist appointment, yet again, that they are still paraplegic and still in need of a wheelchair-accessible house. To be believed and to have that belief recorded as a reference point is an important strength to have in a government bureaucracy; it is a traceable freedom. But that trace is also a source of risk, fear and exclusion. When the houses that appear in an applicant's profile are few, far between, or distinctly different from the houses shown to another applicant they know, how are they meant to feel? What invisible machinations could they speculate are at the bottom of the disparity? The hidden bureaucracy of paperwork is replaced with the hidden work of algorithms, tagging, and database management.

Though the website makes the efforts of this work more visible and potentially open to intervention, the release accompanying greater and more efficient access is coupled, somewhere underneath the coils, with the invisible constriction of the subject. Furthermore, the project requires an integration of the housing applicant within the greater digital infrastructure of ACT Housing and Australian government databases more broadly. This integration happens on the basis of the dividualisation of the housing applicant as an active "part of the functioning of the machine" (Read 2016, p. 240). As Lazzarato argues, "the dividual does not stand opposite machines or make use of an external object;

the dividual is contiguous with machines" (Lazzarato 2014, p. 26), meaning that the dividual is constituted by the same modulatory operations that characterise communication technologies. Homelessness, and the threat of it, is perhaps experienced more deeply as a process of modulation now more than ever before. Smart initiatives, even and perhaps especially when they do not involve shiny gadgets, are engaged in the business of dividualisation.

And yet, it should be stressed that there is nothing inherently oppressive in the modulation of communicative operations, any more than increased visibility is inherently liberating. In this respect, an adequate reading of Deleuze's control society thesis would refuse the notion that control is either inherently good or bad, insofar as such evaluations posit a human that exists prior to the ethical or unethical application of technology. What *can* be meaningfully said about these operations is that they far exceed the transformation of sensed difference into instrumentally and morally valuable data, which the representational framing, with its moral presuppositions, captures.

As Deleuze insists, in the post-disciplinary control societies of digital capitalism, power operates in an increasingly open field (Deleuze 1991). This is directly perceptible in this instance in the manner in which the public housing applicant finds themselves inside an open space littered with checkpoints. Stacey described the current paperwork system as a process that makes ACT Housing "like a gatekeeper for people wanting to move" (interview with Stacey & Phil, March 2019). Rather than exclusively signalling a more nefarious form of control or the destruction of autonomy via connectivity, the continuous mode of power signalled by the website project also makes possible a distribution of autonomy between the technical and the human. Speaking of Japan's high speed train network and the smart card system that allows commuters to onboard and depart trains without calculating individual fares, Fisch argues that such a system allows human actors to "operate with the machine as partners in a novel heteropoietic matrix" (Fisch 2016, p. 125). In this case, the "old", "crunchy", "ineffective", even "torturous" (interview with Stacey & Phil, March 2019) method of re-applying and re-doubling application details with every housing request was not only inefficient from the point of view of the citizen shuffled from context to context, but also arguably inefficient from the point of view of the greater technical ensemble of housing provision. The torturous friction of the old application process is shared by the applicant, ACT Housing staff, and the mixed analog and digital databases themselves (though, of course, not equally). Ultimately, the ACT Housing project speaks to the ways in which the imperative for greater communication can clearly work for and against citizens in ways too variable to consider of equal measure. Modulative regimes of in-formation are also modes of subjectivation, which modulate the diverse potentials of individuation toward the production of certain kinds of individual in the name of 'smartness' and social utility.

After speaking with Stacey and Phil, I couldn't help but relate the despondency that emerged in their relation to smart design to the difficulties that Martin Darcy had outlined to me regarding Queanbeyan's resistance to smart technologies. In one sense, this is a problem that expands much further than the concerns of smart technologies, as a pressing social problem of contemporary governance, education and employment. But it also exposes the way in which the Internet of Things changes the human-technical relationship in a way that modulates bodies (government departments, consultancies, users) into something untenable. As of June 2021, neither the ACT Housing website nor the Queanbeyan open data portal have come to fruition. Since our initial interview in 2019, Stacey and Phil have moved onto other projects and started careers in different consultancy firms. Martin Darcy continues to preside over Queanbeyan's transformation into a smart precinct, but the interactive portal has transformed into an Emergency Alert system for the region. I could not reach Martin for comment, but the Christmas bushfires and the Covid-19 pandemic are likely the reason for the diversion of data and, one might guess, funding. This too points to the way in which modulation produces as much as it dis-establishes in-formative relations.

For both the ACT and Queanbeyan, smartness is an operation that lays bare the human-technical relationship. The Internet of Things — a phrase that stands in for the greater movement of new communicative technologies — enters into these relations as a hoped and promised prophylactic. In these examples, it is easy to see the potential for IoT communication to enable modulatory regimes of control. This is a possibility that I do not wish to deny, though I do want to give more nuance to the manner in which that possibility is understood. Understanding communication as an operation of modulation allows both the technical ensemble of connectivity and the modulatory effects on social life to be attended to with greater attention to the disparities that constitute it. To the extent that these technical ensembles create relations of power, this is not because they mould passive matter, either human (Queanbeyan citizens; the homeless) or non-human (wifi routers; websites; homes; high streets). Rather, these relations arise from the continuous modulation of disparate material and organisational potentialities, in a process that always involves a degree of indeterminacy. In the next case study, we look to the relationality that emerges from ‘smartness’ itself, and the ongoing modulations that characterise a network of boxes and an underground Lab.

Boxes

Entrance to the University of Canberra's IoT Research Laboratory. Image by author, 2021

In the Northern centre of the ACT, the University of Canberra has an underground corridor beneath and connecting its engineering buildings. Halfway down the corridor is an engineering Lab, once a general electronics research area, and now specializing entirely in IoT systems, devices, and bespoke government- and commercially-funded projects. I visited the UC Lab three times between 2018 to 2021. On my first trip in 2018 I met Associate Professor Kumudu Munasinghe, who had been transforming the Lab in recent years so that students could be put largely in control of the development, delivery, and maintenance of bespoke IoT systems. On my second trip in 2019 he introduced me to Nishant and Arsh, two final-year engineering students who had inherited IoT projects from earlier years, and were put in charge of developing new projects commissioned by private companies. I sat down with them both in the Lab, two classrooms joined by a door, which had a strong air of being *in-between*. A continuous desk lined the back right corner of each room, as did a single wooden table stood in the middle. Partially completed projects, clear plastic tubs filled with parts, oscilloscopes, computers, and the detritus of paper and pen work covered all available surfaces, surrounded us with a pleasant cluttering of *things*. A few students milled around, swapping their gaze between textbooks and what looked like tedious coding work, each having gingerly pushed aside these objects just enough to fit their arms, books and computers. If a Laboratory can be defined as a sense of material potential in the making, this was it.

UC IoT Lab. Image by Author, 2021

When I sat down with Nishant and Arsh at the table in the middle of the room — also pushing things just far enough to the side to make room — I asked them to describe how they defined "the Internet of Things" in their work, and also more widely in their field of electrical engineering. To my surprise, they responded with an air of hesitation, bordering on irritation. They made flippant gestures, held up a phone and said, somewhat facetiously, “See? This is an iPhone. That’s an Internet of Things.” We laughed, but it was clear the question brought up a good deal of annoyance. When I asked them to explain what they meant, they were clearly exhausted with the topic:

> What do you do on the internet? You communicate with other people on the other side of the world. We are providing a local internet to the devices to communicate to the other device sitting somewhere else. Thesesensors are communicating to this screen. The sensors in Queanbeyan, they are communicating to a cloud … and they are showing it to the other people. *That’s it*. We are getting the Internet of Things.

Clearly the Internet of Things held little interest for them conceptually, and in practical terms they hardly mentioned it as part of the projects they were working on. However, when I shifted the discussion towards “smart” technologies, and how they defined technological intelligence, the conversation opened up significantly. They both spoke avidly and excitedly about the ways in which the smart environment networks generated sociality and convenience, and they extolled the ability of smart networks, which they themselves had helped build, to perform their smartness. As we spoke, their excitement grew at what truly “smart” systems might do, in a way that a term like “the Internet of Things” clearly could not.

Parts of the UC IoT Laboratory. Images by Author, 2021.

“Smartness”, as it turned out, enabled a much more obvious and meaningful participation between the IoT system and its human users than the term “IoT” tended to imply. Nishant and Arsh were themselves much more interested in the way that technical objects can come into meaningful communication with — and perform services for — humans. For example, one of their projects concerned building a clear Perspex box for a major landfill site that collects methane gas to power “over 30,000 homes in New South Wales”. Nishant and Arsh are designing the box to be light and un-cumbersome, so that it can be carried by an employee to one of 52 locations across the landfill. Over a number of hours, its sensors analyse any gas that rises from the landfill, measuring for the effectiveness of the methane capture, signs of serious leaks, and signs of other, perhaps unexpected gases being produced by the methane capture process. As far as Nishant and Arsh knew, nothing similar existed for the purposes of environmental and safety management at landfills, and they were rightly secretive about it at the time; I was barred from taking pictures of it, and they couldn’t tell me much about its internal workings. What they did share, however, was a keenness and excitement around how useful it would be to the employees and their way of working. They explained:

> **Arsh:** They basically want to know what extent of gases are escaping out of the soil. ... So we build that thing for them [*gestures at the box*] The chamber [is] gonna trap the gases and it will send it to the small chamberup there.
> **Nishant**: And they can carry this along! So we created this device [*pulls out a tablet*] so they can see all the readings coming up here [...] We don't need any internet, it is by line of sight. So they can just keep this device and theycan see the readings
> **Arsh**: yeah basically they can sit in their offices and this thing reports from the field
> **Nishant**: They can email [the data] to themselves, so basically they get the data for the last 6 hours of the day to their email... We made it really easy with these devices
> **Arsh**: That senses it [*points at box*] this displays it [*points at tablet*]... Theyleave it for some time to let the gases get trapped, and they sit with thistablet in their offices, and just run the diagnosis for three, four hours, aslong as they want.
> **Nishant**: so basically it's a pretty huge area, so we have 52 geolocations there, so we've pinpointed them so we go to the exact location, we have GPS sensors in there as well, so we can see which point is that, and what are the levels of you know gases, gas levels up there. Is it safe, is it not safe, what can they do. So they move on to the next location. So basically[...] after going to these 52 locations and all the data from all of these locations, they have an understanding of what the levels are like.
> **Arsh**: It'll create a graph, which will let them know which areas to focus on. And basically they can do a better job and basically trap gases and more economy and everything!

When discussed from the point of view of the UC IoT Laboratory, the familiar claims that smartness makes human life easier are framed as a way *into* the smart node system, as *the* way for humans to continuously enter into a relation with it. *Smartness* related to human activity more than the Internet of Things which, in their view, only pertained to things relating and communicating with each other. Ironically, their reason for dismissing the Internet of Things is attributable to exactly its marketed virtue — it removes the human from the equation. While it might be tempting to assume that this focus on the human rather than the things was a move toward Luddism or indicated a fundamental reverence for the human, much more apparent in these conversations was an interest in what the IoT network connection between objects makes possible for human life.

Boxes, as it turned out, were a recurring theme in Nishant and Arsh's work, and they provide a helpful point of participation into the modulative operations at play in the UC IoT Laboratory. A semi-opaque blue box, emblazoned with the UC logo, holds all the necessary components for a wireless sensor network installed throughout the campus: a motherboard, sensor array, radio and battery. Four boxes have been hoisted onto light poles throughout campus and Nishant and Arsh told me of the plan to expand it to at least a dozen over the coming years. Alongside the wireless sensor network, they are in the process of developing an app that would perform the actuation tasks, including warning students of bad conditions on critical university dates (such as smoke or pollen conditions during exam time), whilst allowing the university to understand how the campus responds to different climatic conditions over time. Protective boxes like the ones shown below are almost ubiquitous in IoT systems and devices, especially in those designed for outdoor use. There are a number of practical reasons for this, including protection from the weather, copyright protection, branding, and insulation, to name just a few. The box itself also plays a role in the system's communication architecture, physically signifying the bundling and segregating of nodes into location-based informants. In what follows I would like to look more closely at the boxes of the UC network; though seemingly banal, they signify important conceptual characteristics of contemporary IoT systems.

UC smart node and the landfill box tablet. Image by Author, 2019

While the boxes could be considered as black boxes, insofar as their inputs and outputs are functionally obscure to the user (Bunge 1963), it would be an error to add to this functional obscurity the kind of conceptual obscurity that Simondon rightly associates with hylomorphic and atomistic ontologies. In such schemas, "the attention is given to form and matter", rather than to what generates these terms; namely, "the process of taking form as operation". Consequently, "there is *an obscure zone* in both cases that masks the operation of individuation" (Simondon 2017, p. 248). Following Simondon, I would argue that to view the technical object as a pre-given form is to conceptually black box it, limiting our understanding of it to its inputs and outputs.

Boxes of the kinds found in the UC sensor network are, to put in Simondon's (2012) terms, specifically "postindustrial" objects. Postindustrial objects are those that express the provisional "unity of two layers of reality". That is to say, they express the provisional unity of "a layer that is as stable and permanent as possible, which adheres to the user and is made to last, and a layer that can be perpetually replaced, changed, renewed, because it is made up of elements that are all similar, impersonal, mass-produced by industry and distributed by all the networks of exchange" (Simondon 2012, p. 13). In the case of the UC network, the perpetually replaceable layer belongs to the boxes and their parts; every component of the box, from the external casing to the raspberry pi within, can be largely mass-produced, have been designed with potential replacement in mind, and will only temporarily interrupt the box's functioning when its parts do break, rather than rendering the ensemble permanently useless. What is permanent and adherent, then, is the smart service itself; that is, the information provided to the network's users through the interface of the app. The postindustrial mode, of which the UC network is now a fairly typical example, sparks a need for a new way of approaching and understanding these technical objects, due to their increasingly and undeniably constitutive role in the production of human life and reality more broadly.

Answering somewhat to this need is Simondon's (2009) argument that we require a more coherent "technical mentality" to make sense of technical objects and, more precisely, to understand them from the point of their individuating capacities. He postulates two fundamental premises that define the technical mentality. Firstly, the technical object can be seen as a series of detachable parts subsisting on a fundamental layer, and, secondly, these objects need to be understood in their "entelechy", not their inactivity, to grasp their mode of individuation (Simondon 2012, pp. 3-4). These two premises are what he calls "cognitive schemas"; they are the cognitive schemas of technical mentality, which, while not entirely separate from human mentality, are irreducible to it. For instance, the UC boxes are made up of replaceable parts; these parts correspond to a fundamental layer of network communication and connectivity; and the boxes themselves make possible the unity of the network reality and the reality of its parts. Each of these aspects are involved with human reality — Nishant and Arsh's work in the Lab, the movements of students across campus, the collection and analysis of the collected data by the University — but they are not reducible to the human, and in fact require a level of independence in order to function. Simondon insists, then, that cognitive schemas are not abstract ideas held in an inventor's or engineer's mind, to be applied to a set of materials to bring about their fruition. To view them in such a manner would, of course, fall into precisely the hylomorphic apprehension of technical objects that he intends to challenge. Instead, cognitive schemas are structures of functioning, which enable a technical object to function as a network of exchange and to unify two layers of reality.

I would argue that *smartness* is the cognitive schema that provides this unity. In a technical sense, to say that the UC sensor boxes enable unity is to say that they provide the means for a provisional solution to the disparation between the network and its parts. It should be remembered that when Simondon speaks of unity, he does not refer to a pre-existing or final unity, but a temporary ‘individualization’ that results from an ongoing regime of individuation. The boxes achieve this unity at the point at which they express smartness, which, in accordance with Nishant and Arsh’s comments above, means that the boxes are ‘smart’ when they *provide a way into the technical ensemble*. This ‘way in’ needs to be maintained by a continuous tension between the individualized elements within and including the box, and the technical individuations that constitute its fundamental layer. What generates this continuous tension, and enables smartness, is modulation itself, which is only made possible by the technical mentality that puts two layers of reality — the series of replaceable parts, and the continuous digital service — into communication. What this means is that the box continuously generates and resolves tensions and disparities to bring the network into a common system of information exchange. That is to say, the box continuously in-forms the IoT system in a continuous and variable manner; it *modulates*.

Nishant and Arsh gave a useful example of this modulatory operation after I asked them what they believed constitutes a ‘smart’ technology. Nishant replied enthusiastically, speaking of another sensor network that the Lab had developed for a local arboretum:

> **Nishant**: I can give you a very good example… The arboretum nodes [are connected] to a weather service, right. So if there’s rainfall predicted in thirty minutes… All of these nodes can then change their sleep time from five minutes to two minutes. So after the rainfall has happened, they change their sleep patterns from two minutes to five minutes again. So they do it all on their own. They don’t need any control from humans… That’s smart by itself, right? The devices know if the rainfall’s gonna come,and they change

their sleep cycles. So basically you don't have to do anything, you just sit back at home and relax.
Arsh: With IoT you can say that it does it by itself, no human efforts are needed.
Nishant: So basically that's my definition of smart, so they understand the surroundings so they can sense and they change according to their environment, and they basically make life for humans a lot easier.

In this example, the sleep cycle of the sensor nodes modulates, as a way of integrating the tensions between the moisture sensor probe, the Internet-provided weather report, the open database that requests and records the network's transmission, and the trickling of the rain into the soil. In modulating, the sensors achieve a unity as a network that can meaningfully and reliably communicate and respond to their environmental conditions. Boxes contain these modulative processes and further unify the sensor network as a metastable yet continuous technical system. And, significantly, this technical process of modulation is (for Nishant and Arsh) equivalent to smartness itself.

Viewed from the perspective of technical mentality — that is, with a focus on the activity of the boxes as a mode of unity for two realities — a Simondonian perspective enables us to raise important questions about the precise forms of control with which they are entangled. Simondon famously figured the problem of man's alienation with respect to machines as a fundamentally technological, rather than social or economic, one. It was not, he suggested, socio-economic oppression in the first instance that alienated man from machine; Simondon's concern was to theorise "a more general alienation than the one situated on the economic level" (Combes 2013, p. 74). This, according to Daniela Voss (2019), is one of the real limitations of his thought for understanding the character of contemporary work under the conditions of technological capitalism. Voss (2019, p. 5) criticises what she regards as overly celebratory accounts of “the apparently self-sufficient, intrinsic aspect of technological functioning”. And she insists that Simondon’s account of technical evolution and invention is insufficiently critical to address cognitive capitalism’s exploitative generation of value via “innovation”. In a slightly less critical consideration of Simondon’s value for understanding contemporary technical invention, Stefano Mazzilli-Daechzel (2019, p. 243) argues that contemporary spaces of invention, such as the UC IoT Laboratory, represent both the conditions of possibility for the “pluralist ontological perspective” of the technical mentality, as well as a frustration of its potentials. On the one hand, technical invention is undermined by “the ways we relate to technology in the realms of production and consumption”, and on the other, the technical objects made by makers approximate the “open objects” that Simondon identified with technological invention and evolution, insofar as “makers exhibit tendencies towards more open forms of design” (Mazzilli-Daechzel 2019, p. 243).

Such a tension was certainly apparent in the way that Nishant and Arsh described the organisation of the UC IoT Lab. They both spoke highly of Kumudu Munasinghe, their Lab leader and head of WSN engineering at UC. They described their experience of the Lab as challenging but also very rewarding, as Kumudu encouraged an open style of work. “When we started [at the Lab], we didn’t have the skills”, Nishant tells me. “In the first two weeks we probably couldn’t even work the raspberry pi right… But within a couple months we were fine", thanks to Kumudu in particular, who they acknowledged was working to strict industry-mandated deadlines but didn't pass that pressure onto the students. "Working with Kumudu is easy. There is maybe a space [...] where there's not constant pressure". Arsh, who comes from a mechanical engineering background and had no experience in electrical engineering before joining, was also particularly grateful for the support and freedom provided by the other Lab members, who "helped us, but they weren't like, spoon-feeding us. They're like, we'll tell you how to do it, but we won't do it for you". "Before we came here," Nishant interjected, "we were so dependent on somebody else teaching us. [Now] we really understand how important self learning is... The self learning is the best thing we learned in this lab". What self-learning amounts to is a continuous access to information resources like books and the Internet, combined with support from their leaders and peers, as well as free access to the Lab's resources and a space to experiment. In one instance, Arsh recalled, Kumudu gave him a raspberry pi with unsupported hardware that needed to be upgraded; "He gave me a raspberry pi, he gave me a book, and he said you have one week to figure out how to get [the data] out of it". We all reeled back together at what a task that would have been, but it soon erupted back into laughter. Regardless of the challenges they described, be it tight deadlines or software incompatibilities or a completely new skill, Nishant and Arsh were quick to laugh, and quick to credit their success to the UC IoT Lab's positive environment.

Whereas this style of work may indeed potentialise the Lab and its members, it could just as equally be read as a more typical example of the kinds of cognitive capitalism that Mazzilli-Daechzel, Voss and others attribute to the industrialization of makerspaces and the university sector more broadly (see Elam & Wiley 2020; Kostakis, Vragoteris & Acharja 2021). This is not to undermine Nishant and Arsh's rather genuine enthusiasm and gratefulness regarding the UC IoT Lab and the opportunities it afforded them during their undergraduate degrees and into their graduate studies. Nishant, for one, is now a PhD student at UC specialising in blockchain, and tells me he will soon become the IoT Lab's part-time lab leader. Rather, in recognising the material and political relations that make the UC Lab itself possible, the cognitive schemas that arise from inventions such as the UC smart node system, and the manner in which they achieve a level of unity, can be analysed and appreciated from within a greater technical mentality.

Mazzilli-Daechzel raises the important question of what stands in the way of the realisation of the potentials of these spaces of technical invention. His own interest is to protect the possibilities for a democratic approach to technological problems by a citizenry with sophisticated technological understanding. I would suggest, however, that this is to foreclose the potentials of spaces such as the UC IoT Laboratory through a focus on a recognisably human(ist) version of the political. For this reason, I think it is worth enquiring further into the kinds of technological objects represented by the sensor boxes to understand, in the first instance, the conditions of the unity that Simondon identifies as crucial to the functioning of such objects. Unity, and its cognitive and technical prerequisites, present an opportunity to question how modulation constitutes the kinds of power relations that emerge from even the mundane instance of the protective weatherproof box. Its simplicity enables more complex relations, such as a post- industrial technical mentality; the subjectivation of students as innovators; the pressure for industry-ready inventions; and the instrumentalization of technical education, to name but a few examples. When faced with these potential relations of power, what becomes important is not to seek out the ways in which these relations might be homogeneously applied or read into each instance of the technical ensemble, but instead attend to the disparate realities that make their relative stability and unity possible. In this instance, such a reality involves the ongoing modulation of smartness.

My aim in this discussion was not to suggest that the sensor boxes are exemplary instances of modulation, though the ubiquity of 'the box' in distributed communication networks typical of the Internet of Things does provide a useful pathway into rethinking conventional analyses of their relations of communication. Rather, my aim was to illustrate how even the mundane instance of boxes can be reframed through an application of Simondon to rethink it through its individuation, as an ontogenetic process tied to a technical mentality — which, in this instance, is to rethink the box according to its modulative capacities and thereby avoid a mode of analysis which would immediately pose human life and modulation as opposing forces. Indeed, as we will now see with the final case study in Claim I, modulation is a vital and thoroughly material operation in the invention of complex and evolving communication networks.

Cow tags and a shed

Tom in his buggy, a prize bull in the background. Image by Author, 2019.

Tom Gunthorpe is a farmer in Yass, New South Wales, who works on his family-owned property, Mt Buffalo. He raises sheep and cattle for meat, wool, and breeding stock. I met him in the middle of the 2019-2020 Christmas bushfire catastrophe. The fires were the next in a line of ecological downturns for the farm, arriving not long after a decade-long drought — "2007 was when it forgot to rain for ten years". When I pulled up to Tom's house, overlooking Mt Buffalo's rolling pastures, the sun was out and the winds were high. Tom came out to greet me in his front lawn, wearing a radio that blared out local fire warnings. He had been out fighting fires the week before, and as we walk into his home he looks worriedly out at the yellow grass and high winds. “We may have to cut the interview short. Might be too dangerous to go out on the buggy.”

Overlooking Tom’s property. Image by Author, 2019.

Tom Gunthorpe’s property is big. “Everything you can see to the horizon. And that much again.” The horizon is kilometres away. Tom shows me satellite pictures of his property in an app that he uses to know where his livestock are. He can open the app anytime, look at which paddock the cows and steers are grazing and sleeping and breeding in, and then get into his buggy and drive out to them. He knows where he has to go when he needs to round them up or check on them or make sure they’re feeding and drinking. If they haven’t, he knows. He can see that they haven’t physically gone to the water trough because that's where their tags update. He can go and find a cow whose tag hasn't updated in hours and see why she hasn't had water that day.

Before he bought the 2,100 acre farm from his father in 2000, Tom was in the electronics repair business, at one point developing complex communication networks for clients like Telstra. Towards the end of his IT career he developed an interest in small autonomous sensor networks, fascinated with the process of making each node transmit as much data as possible. In 2014, after he began working on the farm full time, Tom received a government grant to develop Agriscan: a smart ear tag system for his livestock. Unlike government standardised ear tags, which only track GPS location, Tom's tags connect to physical ensembles, including mechanical drafting gates. Drafting gates are generally used to separate livestock by particular characteristics, which are generally predetermined by the farmer before the livestock approach the gates. Most commonly, gates are used to separate livestock into vaccinated and unvaccinated, or keep and sell. With Agriscan, each animal's tag is read as it approaches the drafter. Its characteristics are noted, it is weighed on the scales, and then ushered left or right. This speeds up the process of livestock sorting drastically, providing monetary gains and keeping his ITC skills "up to date" in the increasingly competitive field of "agtech".

Agriscan's real efficiencies, Tom tells me, come from its ability to predict and manage livestock in a highly customizable way. Tom is in the middle of developing a website portal for Agriscan, wherein users can set and monitor variables against each animal in order to reach particular goals. For example, Tom can accurately determine which cows and sheep will reach target ages, weights, pregnancies, and vaccination milestones by a certain date. This would allow him (and has done) to sell them as quickly as possible (in the case of drought or high meat prices), or according to a predetermined schedule (in the case of major export deadlines). Equally importantly, it allows Tom to know when particular livestock aren't meeting weight or breeding goals: "I very intentionally cut out the non-performers. I've gotten very good at that". Since he has started selling non-performing livestock early, his profit margins and feed-to-weight efficiencies have increased dramatically. This is an important success for Tom who, when he began farming, says he used to look at other successful farmers and wonder what he was doing wrong. Now, as he puts it, he's the one that other farmers look up to. "I'm the one doing things right".

At this point, to attribute the dynamics of Agriscan as entirely captured or capture-able by the forces of neoliberal capitalism (or any other profit-centred enterprise) is in some respects tempting. Certainly the potentiality of spaces like Tom's shed have not gone ignored in the literature, nor in the discourses that emphasize the profitability of "think tanks", "innovation labs" or even more communally minded "makerspaces", as mentioned earlier in this chapter (see also Cunningham 2017). Equally, capitalist instrumentalization is clearly present, most obviously in the productivity and efficiency gains of capturing the viability of each sheep and cow. To put it in Manning and Massumi's terms, this instrumentalization of potential is typical of contemporary neoliberal capitalism, which captures:

> entire fields of emergent relation. [...] Capitalism endeavors nothing less than the universal capture of forms of life. It subsumes them, sometimesgently, more often brutally, to techniques of relation dedicated to quantitative value-adding and accumulation (Massumi & Manning 2014, pp. 121-122).

In the domain of agricultural technology, livestock are habitually subjected to such “techniques of relation” that capture them universally, “from paddock to plate” as it were. Though farmers themselves are, of course, not entirely exempt from this process. A few months earlier I had interviewed Sean Starling, a representative for the Meat and Livestock Association of Australia who specializes in helping “SmartAg” products find their way to market. Anticipating my interview with Tom, I asked Sean what he believed the Internet of Things does for farmers in their everyday lives. “Peace of mind” he answered, quickly. “And cultural capital”, which these days often accompanies the ability to make “smart” agricultural decisions to “get ahead” of traditional, often costly, farming techniques (interview with Sean Starling, June 2019).

When I spoke to Tom a few months later, I brought up this idea, asking him whether he thought the Internet of Things could bring a level of peace to farmers already overburdened by drought pressures, not to mention fire. But Tom frowned. “I’ve never heard it put that way… I just consider it to be a tool”. Tom then recounted a potential buyer asking for cows with a minimum weight by a certain date. Usually the method would be to use common formulae for livestock weight gain (e.g. so many kilos of food per day will result in so many kilos of meat added per week) and, as Tom put it, “hope for the best”. Tom, however, decided to put Agriscan to the test. He consulted the database to know which cows could possibly get to the minimum weight by the deadline, while filtering for other factors like vaccination schedules and keeping his most prized cows for himself. Given a constant weight gain potential — in this case, 0.05kg per day — Tom was able to chart a feeding plan for his chosen animals, and accurately predicted their total weight gain within a 5% margin. This method also allowed Tom to determine which animals would "never meet their genetic potential" in terms of weight gain, and either sold or separated them from the more intensive feeding program, to prevent "wasting my feed". The sale of the cows by the due date was able to fund Mt Buffalo's operations through a critical period of the drought, when feed prices reached a record-breaking high. Agriscan's ability to capture livestock as well as Mt Buffalo's practices as a whole was crucial, not only for the farm's financial viability but also for Tom's viability as a farmer.

Yet even in this example, where the profitability of Tom's farm is systematically captured, turning to theories of capture would not be adequate to the modulating forces that also characterize it. As clearly as Tom and his devices participate in the modes of capture of contemporary neoliberalism, there is more to be discovered in the technical ensemble of Agriscan in its entelechy. Probing this requires, for a moment, setting aside the important and viable concerns set out by Massumi and Manning, and engaging with the ways in which disparate levels of reality find temporary solutions in Agriscan and its accoutrements, the apps on Tom's phone, and the tinkering electronics in the shed. As I will explore below, Agriscan, and more specifically the zones of metastability from which it emerges, exceeds systems of capture.

A desk and a box full of cows. Images by Author, 2019.

Tom's concerns, as well as his pleasures, are a world away from academic diagnoses of the Internet of Things that figure it as a harbinger of deeply capitalist forms of control. Halfway through the day, Tom leads me out from his living room onto his porch, into the dry heat, past a vibrant green patch of lawn which he'll bring me back to later, and into a Colourbond shed. The shed is where he handles the business side of Mt Buffalo — and it's where he put together the first physical prototypes for Agriscan. As I walk in, I can see empty sensor node carcasses on a long wooden bench, which is covered in soldering irons, hand tools, pieces of Perspex, wire harnesses, small opened packages, and piles of other crafting paraphernalia. The workbench shares a corner and spills over into a wall lined with bookshelves, which are stacked to the brim with volumes. On the opposite wall is another long wooden bench, though this one is lower to the ground and has two computer monitors mounted above it. The desk is covered in papers, a keyboard and mouse, a raspberry pi, a phone, and scatters of notebooks and pens. In the centre of the room, carving out narrow paths between each of these zones, are two large cardboard boxes. They are filled with Tom's custom ear tags. The tags are packed in a cardboard box loose bags; you could stick your hand in and it would go up to your elbow. I took a picture of a single tag, but afterwards Tom asked me not to keep it; the tag ID is clearly readable, and he hadn't registered them all yet. That's one of the problems with current government regulations around tags, he opined. "I've bought all these tags, and the government registers them as actual cows I've got. But these aren't cows, they're tags in a box". Far from totally capturing the vitality of Mt Buffalo for maximum profitability or protection, the box of tags spill out a potentiality that both exceeds and is exceeded by the system of management that claims to capture precisely that excess.

Were we to submit Agriscan — and Tom's methods of farming more generally — to a strictly critical reading, we would likely uncover fire trails of bio-surveillance, dividualizing data, or the political precarity of climate change winding all the way through his fields, his house, his shed, and the single patch of green grass in his front lawn. And no doubt the traces of these recognisably politico-social concerns are there, but their explanatory power over the constellation of things, ideas, flows of energy, mistakes and transformations of Mt Buffalo farm are limited.

I'm enjoying watching Tom walk between the workbench, the boxes and the computer, watching him grab for pen and paper as he explains the concept of the cloud and how different layers of data talk to each other, and sitting beside him as he walks me through the backend of his Agriscan website. Our conversation at his kitchen table was a personal and often political discussion about Tom's life and his values; he told me about his father's death and buying his farm from his siblings over a shared bag of salad and croutons. This part of the interview feels more intimate and operational. We share less eye contact and spend more time looking at the same objects, gesturing, turning back and forth in our chairs between the benches and the boxes, mumbling between sentences, checking our phones, laughing less often but more spontaneously. “This is why IoT is fun today.” He chucks down a small device onto the desk and points at it. “That is a LoRaWAN node. There’s the radio. We’ve got all of these points here where we can connect in sensors. So I might have a soil moisture probe, I might have a gate sensor… I might have temperature sensors, I might have rain gauges, whatever. Whatever you want*, I can plug into that*.” Despite the encroaching uncertainty of fire, drought, and bankruptcy, “plugging in” to Mt Buffalo still generates in Tom a sense of excitement and joy — not least because it accords with the potential for value, but not only because it does so. For Tom, the Internet of Things is a profitable but also joyful opportunity to come into communication with the farm and the way it unfolds in his everyday life, in such a way that gives a stability to those operations of his farm that, as he knows all too well, are in fact always in flux.

Taken on their own terms, at the level of their materiality and technical reality, what is clear is that each of the zones of the shed work differently. The workbench is a building zone, modulated by the solder, the small opened packages, the layout of tools and materials that suited the time they were set down but will need reminding when they are picked back up. Each element is ready, open for interaction, fully operational once the mental schema catches back up. The computer desk is a more tempered and concretized zone. The computer, a stray raspberry pi, and the notebook and pen are the elements which light up the ensemble, and they all attach firmly to the digital operations on the monitors, keyboard and mouse. The cardboard boxes full of tags are, perhaps counterintuitively, the most complex of these zones. There are a number of layers of operations happening in the centre of the shed. The boxes are large, taking up any extra free space and dramatically shaping the paths of movement through the shed. They're open, but not emptied; the bright tags are waiting. It is the least mobile of the zones, though they express the purest potentiality. Maximum potential can perhaps be found best in immobility, because it has not yet found its system of compatibility which would lead it down a path of concretization. As soon as the boxes migrate to the workbench, this zone's potentiality is put into flux and uncertainty (how do I make this work?) until it sparks, suddenly, into a new regime of operation. A solar cell and a battery are not a functional energy system, until suddenly they are. Each of the zones that mark Tom's sheds are not discrete areas, but are metastable, and can connect to each other *because* they are so. The difference between these zones is clearly not solely quantitative — they all deal in digital, material, and living information in some way — but is also deeply qualitative. Each zone puts very different processes into operation. When Tom interacts with each zone there is a reciprocal modulation: Tom as a farmer who other farmers look up to; Agriscan as a kind of finicky and beautifully operative device; the farm as an unwieldy, vulnerable, productive piece of land. Recognizing such relational engagements — and what's more, their basis in indeterminacy and disparation — gives an important technical basis to any analysis that would seek to critique the modes of power at play.

In this account of the cow tags and the shed, it was my intention to resist habitual modes of critique in order to discover what, if anything, might also be at play in nascent IoT systems like Agriscan and the ensembles that enable its development. In addition to its more immediate potentials for profit and the capture of life, there was also an abundance of other individuations to be discovered. This excess works at disparate levels: the kitchen table, the shed, and the farm are connected like the computer desk, the workbench, and the cow tag boxes are connected; not by Agriscan itself, but by the *individuation* which produces and remakes these zones (within the shed, and within Mt Buffalo). Agriscan emerges in the disparate levels as a constant *modulator*, bringing the disparate into metastable regimes and operating in their shared margins of indeterminacy. In sum, if we consider connectivity as an evolving problematic that finds provisional solutions in a given IoT system and its required milieu, theoften reductive and blocky critiques of the Internet of Things and the simplistic valorisation of connectivity lose much of their explanatory power. What is left tobe discovered is nothing less than an entire world of technical activity.

In this first set of Claims, the modulatory capacities of communication have been explored with an eye towards disparation, metastability and indeterminacy. Doing so has opened up the operation of communication and provided productive methods of resisting a representationalist analysis, which would reduce IoT communication to connectivity and control. Crucially, by focusing on the disparate as the basis of an IoT system's relations, the operation of sensing (which, in IoT systems, similarly involves a mode of communication) can also be approached as fundamentally based in difference rather than similarity. Such a move is important in order to challenge the equally reductive understanding of sensing as intelligibility. It is commonly assumed that technical progress lies in the ability of technical objects to represent the world to greater degrees of fidelity. Yet, as we shall see, the operation of sensing is better understood as driven by transformation and, as is the case in smart sensing, integration. With this in mind, we can gain a more adequate grasp of the real forces of transformation involved in IoT systems and their capacity for instrumentalisation.

4 Sensing as Concretization

What precisely is included in the act of sensing? Modern sensor networks, which integrate rudimentary sensor functions into a wider computational array, complicate this question. Are sensors, sensor networks, and sense data separable in any meaningful way?

The types and quantities of sensors worldwide has increased exponentially — physical, chemical, and biological sensors are currently sold each year by the billions; by 2022 they are expected to sell by the trillions, thanks in no small part to the Internet of Things and other Wireless Sensor Network (WSN) applications (Potyrailo 2016, p. 11881). In a 1995 publication from the US-based National Research Council, the authors of the report bemoaned the fact that the field of sensor research was “plagued by ambiguity in definitions and terminology” (National Research Council 1995, p. 10). Yet the report still defines both sensor and transducer as: “a device which provides a useable output in response to a specific measurand”, with ‘output’ meaning “an electrical quantity” and ‘measurand’ meaning “a physical quantity, property, or condition which is measured” (Instrument Society of America 1975). This definition of sensing as a general technical operation has not changed in almost five decades, though the ways in which sensors have integrated into other technical ensembles has transformed enormously. The Internet of Things has accelerated this transformation, introducing novel challenges and solutions to sensing in increasingly diverse environments and devices. Specifically, the development of the Internet of Things has led to a common combination of RFIDs and WSNs to integrate sensor data with location/identification services and the broader communication architecture and energy needs (Landaluce et al 2020). Rudimentary sensor nodes are still available as individual elements, but for IoT applications — which increasingly tend toward high-density, low-power, distributed configurations — the more integrated a sensor can be, the better.

Considering this significant change in the genesis of sensing, brought on significantly (though not wholly) by the development of the Internet of Things, the role of sense data in this new regime of functioning should be reconsidered. Outputs and measurands remain the major modes of technical sensing, though the field of operation in which they function — and therefore, the modes of individuation that accompany them — has significantly changed. Reconsidering the operation of sensing, therefore, requires a dual approach. Firstly, it requires a reconsideration of the act of sensing and its relation to the way it claims to make the world knowable via its measurand and outputs. And secondly, a reconsideration of the technical reality of sensing as an operation that is deeply and increasingly integrated into a wider technical ensemble.

To address the first part of this problematic, this chapter will interrogate the production and use of sensor network-generated sense data, and the common understanding of sensing as a process of producing *intelligibility*. Specifically, the operation of sensing is commonly understood as an operation of making-intelligible something that pre-exists the operation of sensing. From this point of view, there is a direct relationship posed between sensation and the act of sensing: sensing makes sensation intelligible. What has been witnessed in recent years is an enormous pressure on sensor networks to provide the data necessary to understand the transformation of the world, which continues to be — has always been — complex and interconnected. In technological discourses, the role of sensing is not only to capture transformation, but to render it knowable and usable — by machines, if not their users. Sensing is thus posed as an operation which reveals an invisible world ready to be recouped by human and non-human knowledge. Indeed, one of the claims that is frequently made about the Internet of Things' novelty is its ability to "make the invisible, visible" (Thales 2019).

Critics who address such implications of extensive sensor networks have extensively engaged with the problem of the political economy of sense data, as well as the anxiety that sensor networks play an increasingly dominant role in matters of public policy. As it has been long established in sociological discourse, sense data is usually taken as objective and unmediated, which, while instrumental for any number of technological and scientific systems to function, can lead to troublesome political scenarios when applied and installed in human affairs (Beraldo & Milan 2019). Lupton (2020) points out that the Internet of

Things in particular has generated a sense of increasing and unstoppable "dataficiation" of people, places and things by the "apparent all-seeing power of digital technologies such as IoT devices" (Lupton 2020, p. 5). Predominately, the concern around sensa data and its use has concerned the connection between science and power. Access to the objective nature of a phenomenon, and also to the ability to generate objective recordings of a phenomenon, are crucial tools for claims to power and legitimacy. Sensor networks, with their claims to represent such objectivity to greater degrees of accuracy and precision, thus pose an ongoing political and ontological challenge.

Fortunately in the social sciences we have a long history of critiquing sense and intelligibility, especially from feminist STS theorists such as Donna Haraway and Isabelle Stengers. Haraway (1990, 2016) and Stengers (2003, 2018) have explored the new regimes of intelligibility offered by new technical ensembles, especially in relation to the ways that the old language of capture and making-visible are attached to new technological bodies. We could think here most clearly of Haraway's informatics of domination, which illuminated the new vocabulary of capture accompanying new techno-cultural regimes of power, and which inaugurated a mode of sensing aimed at the identification of life towards exploitation (Haraway 1990). Most recently, in *Staying with the Trouble*, Haraway's focus is on finding ways to "question the tissues of one's knowings" through new (and old) modes of language, games, and tentacular symbiogenesis, which refute the order-language of technoscience and are able to accommodate "nonanthropocentric difference" (Haraway 2016, p. 122). Stengers' critique of the sciences is more pointed at the way in which vast techno-assemblages are coordinated towards the capture of science, as well as scientists, in an ever-more "straightforward relation of capture" (Stengers 2018, p. 45). Her call for a "slow science" calls on scientists to allow themselves the time to experience the "bewilderment" and "shock" of events captured with scientific apparati. More importantly, she asks scientists to pursue those events more intensively in order to grasp their full meaning, and to resist the disciplinary demands of the technosciences to evaluate and valorise all identifiable scientific knowledge as it is produced (Stengers 2018). For both feminists, the capture of the world by technoscientific apparati remains a crucial field of political intervention, with the aim of enabling encounters which might generate greater kinship (Haraway 2016), or a "future worth living for" (Stengers 2018, p. 227).

Intelligibility, and the technosocial processes that produce it, require our ongoing attention and creative intervention. The role of sensing and sensor networks in deliberating social problems are at the centre of this work. My contention is that this work cannot be done without a greater understanding of the technical reality that generates and is generated by the operation of sensing. This chapter will make it clear why sensing is not simply a process of bequeathing intelligibility (and along with it, ideologies of various sorts) to something given via an objective recording. In doing so, my aim is not to investigate the practices of technoscience as Haraway and Stengers do, but to look to the ontology of technical sensing. Remaining within the realm of technoscientific practice requires a level of commitment to representationalism that should be questioned, as it entails an ontological claim on reality as much as a political one. A more precise look at sensing's technical reality, specifically through a processual framework, will allow me to examine the presumptions upon which these established practices are based.

Descriptions of the Internet of Things that stress intelligibility are correct in one sense; certainly the transformation of the sensate world into a form that is intelligible to the sensing machine is key to its operations. Yet this is not an innocent scientific claim. It is an ontological claim about the nature of the world. IoT sensing is deeply animated by the claim that to sense a phenomena is to make it intelligible. Yet, as I have been suggesting, we miss much of the technical reality of a system such as the Internet of Things by subscribing to such assumptions and the ontological frames on which they rest. It is with this in mind that this chapter interrogates these ontological and indeed political claims, with an eye to better understanding the nature and potentiality of the production of milieux through sense.

To address sensing within a processual framework first requires addressing sensing as it operates within the realm of intelligibility, and then turning to other concepts to move beyond this realm. Section 4.1 will discuss the technical and philosophical reasons for sensing's place as a translator and captor of the world into human frames of reference. Counter to this history, I look more closely at the technical operation of sensing and argue that transformation, not representation, is its basis. This shift in focus, from representation to transformation, is key to grasping the ways in which the technical operation of sensing exceeds the frameworks of intelligibility, and the human-centricity that attends these frameworks. Work by other scholars, especially by Jennifer Gabrys, have already indicated that shifting away from human models of sensing and perception — and implicitly, human models of intelligibility — allows us to problematize sensing in a way that is more clearly in line with its operations of transformation; that is, its technical reality. Section 4.2 will discuss how that technical reality, as well as involving transformation, involves the integration of sensors into their surroundings. This is especially the case in the evolution of IoT sensor networks, which claim to increasingly make the world intelligible by integrating sensors more deeply into it. I turn to Simondon's concept of milieu to address what it is that IoT sensing actually instrumentalizes and makes available to the IoT system as a whole; namely, the co-individuation of entities and their unique environment. This is especially reflected in the evolution of IoT systems towards service-based functions, which requires sensors to generate an associated milieu in order to function. With an eye towards better understanding the ontological operations of integration, section 4.3 then turns to Simondon's concept of the concretization: the process by which technical objects evolve, making their functions more "concrete" and internally coherent. The chapter presents a new understanding of sensing as a process of concretizing a field of potential and generating an associated milieu, which can then be rendered intelligible. From this point, the role that sensing plays in the social determination of problems can be evaluated more clearly on the basis of technical reality.

4.1 Intelligibility

As the unfolding of the Covid-19 pandemic in Australia has exemplified, the manner in which we understand human movements and events is today deeply inflected through the technical. Kristina Keneally, shadow minister for Home Affairs, appeared on the Australian talk show program Q&A in late 2020. During an interview Keneally passionately decried COVIDSafe, Australia's national contact tracing app, as an unequivocal failure:

> This COVIDSafe app from the Commonwealth was supposed to be our ticket to freedom. It was supposed to be our way out. It hasn't yet found one unique contact that wasn't already found by manual tracking and tracing. The New South Wales Opal card has done a better job at tracking this coronavirus than the COVIDSafe app (Kristina Keneally, *Q&A* 7 September 2020).

The political motivations underpinning this evaluation of the COVIDSafe app aside, it is notable that the starting point of this discussion is the idea that a tracing program, with all the surveillance it implies, could function as the 'way out' of the social crisis brought on by the virus. The patent disappointment in the actuality of the app is inseparable from the hopes invested in it as a means of preserving personal liberties, and as a technological fix to an unwelcome disturbance in the social fabric. Yet, given the desire to deploy a technological fix toward a return to the supposed normality of pre-Covid life, it is perhaps unsurprising that the sensing capacities of the app are figured in these hopeful terms. To the extent that COVIDSafe represents a means of producing sense data that is both intelligible and usable, it also represents the possibility of preserving the familiar sense of the world in which humans (rather than viruses, or indeed technologies) master the forces of the world. In any event, this desire to preserve the state of affairs proper to a human-centred universe explains in large part the prevalence of an ultimately reductive account of sensing operations; namely, the characteristic reduction of sensing to the production of usable data, and the correlative reduction of sense technologies to devices of intelligibility.

With respect to the question of the Internet of Things, what is of concern to me in this chapter is the manner in which its sensing capacities are conceived as a way of capturing life and rendering it as intelligible and usable data. What such narrowly instrumental constructions of technical sensing obscure is the much more complex and potentialised reality that even a simple technical sensor like the COVIDSafe app entails. For instance, though this network could be formally defined as the app and its users, it also involves a number of other elements, individuals, and ensembles: the public architecture that congregates or disperses virus vectors, business practices which enforce or ignore Covid check-ins, virus particles clinging to surfaces, and the greater flows of commerce and cultural rituals that initiate mass waves of sensor readings, to name a few. What becomes of this enormous network of movement, habit, and change when sensing is figured primarily as the act of making-intelligible? My concern here is not that sensing produces a usable output, nor that this process creates a kind of knowledge about the world it claims to sense. My concern is instead that the production of such knowledge, and the focus on the usability of sensing's outputs, involves a set of presumptions about the ontology of the milieu being sensed. Such presumptions encourage a disposition towards sensing and sense data as ultimately representational of a pre-given reality. When our analytical and ontological frames start and stop at the constituted individuals who 'use' technology — as if their own constitution were entirely external to its operations — what becomes of the multiple realities that constitute and extend beyond those individuals? In what follows, I will argue that when intelligibility is taken as both the process and the goal of sensing, sensing is reduced into a simple operation of representation via transformation.

The correlation between intelligibility and the sense provided by technology is deeply rooted in the historical development of the sciences, which in turn was synonymous with the development of early metaphysical models or "natural philosophy" (Dear 2008). Metaphysics that have used human perception as the model for knowledge about the world have had a particularly strong influence in this regard. In particular, Transcendental Idealism as developed by Immanuel Kant attempted to establish an epistemology of the human senses as the foundation for a reliable and rigorous knowledge of the world. Transcendental Idealism holds that objects are the product of a pre-given synthesis between diverse operations and forces. This synthesis does not happen when we experience an object, but at a level that transcends experience; it is a synthesis that occurs "independent of experience and as the condition of possibility of experience in general" (Jones 2009, p. 105). To distinguish actual objects from those that can be conjured by the imagination, Kant argues that objects require sensibility to be known rather than merely conceived. Once furnished with sensibility, thought about an object is elevated from being "metaphysical speculation" to an act in which we can truly 'know it' as a "possible object of experience" (Jones 2009, p. 105). This true knowing is only related to "how our cognitive apparatus makes its own sense" of objects, never independently of their sensual phenomena (Jones 2009, p. 105). Transcendental Idealism can thus be said to position the work of science as the endless pursuit of greater degrees of intelligibility through the refinement and enhancement of human senses through technological ensembles.

Sensor networks are, in the popular and technical imagination, routinely inscripted into the project of the production of modern scientific thought, and to this extent they inherit the presuppositions of this idealist, human-centric model. Understood through a Transcendental Idealist model, sensing networks are thus conceived in terms of their capacity to confirm the relationship between real sensation (as a product of transcendental syntheses) and the possible experience of that sensibility (which can be grasped by the mind through the technological apparatus, rendering the object intelligible). As technological organs, they are tasked with staying faithful to the form of the object by re- presenting it according to forms of intelligibility. Though the tenets of Transcendental Idealism ultimately lead to an understanding of objects that is always partial and incomplete, Kant argues that this nevertheless produces a strong basis for humans to collectively recognize objects as bundles of sensation that can be verified according to operations independent of human perception, thus uniting collective apprehensions of objects and making scientific thought possible. What is important here is that *objects*, or *individuals*, which are determined by pre-given operations, are the *goal* of sensing, and are also the objects around which thought (especially scientific thought) concresces and advances.

The claim that the collective recognition of pre-given objects is the scientific basis of thought leads to other, broader claims about the sociability and organization around such objects. In the example of smart city systems, the collected sense data, as well as its representation through public interfaces, are directly correlated to greater collective recognition of the city as such and, thereby, a greater potential for interaction with it. Although government programs for full civic participation in smart city programs are still largely in their nascent stages, there are now a number of smart city installations that have been designed with public interaction in mind, allowing citizens to view collected data and contribute their own (see Sahib 2020). These public interfaces into the city are often framed as citizen-centric initiatives that involve the public (whether directly as stakeholders or indirectly as contributors) in decision making and policy, allowing citizens to be considered "experts" in their local area (Tadili 2019; Dardier & Jabot 2020; Sahib 2020). These initiatives emphasize that smart city and citizen sensing leads to more informed decision making (Jalali, El-Khatib, & McGregor 2015), a greater sense of community (Capdevila & Zarlenga 2015), and a better ability for citizens to "express themselves" (Hill 2013). Such claims tend to be made on the basis that generating, accessing, and sharing local sense data enables novel and detailed representations of a city's many moving parts. The greater representation of life within a smart city, enabled by its sensor nodes, networks and interfaces, is cast as the pathway to increased democratization and overall quality of life (Neirotti et al 2014; Yigitcanlar 2015;

Pereira et al 2018; Sharma 2020).

What is significant here is that, according to this model of human perception, the operation of sensing is inseparable from an operation of synthesis of pre-existing forces and principles. Much post-Kantian thought has challenged this model of human sense, and Deleuzian thought in particular has sought to free the faculties from their synthesis in the subject. While Deleuze espies genetic potential in Kant's transcendental enquiry into the conditions of the given, he bemoans the fact that Kant lifts his model of thought from the empirical experience of a human subject in relation to its objects. As Paul Bryant puts it, "The opposition between the sensible and the intelligible is not even operative in Deleuze's ontology. As such, there can be no question or problem of the schematism for Deleuze insofar as there are not two terms requiring the mediation of a third term" (Bryant 2003, p. 28). With respect to the sensing capacities of the Internet of Things, my concern here is that deriving the model of technical sense from this particular — if in many respects historically dominant — account of sense leads to the positioning of such technologies as proxy devices for an essential mode of knowing and relating to the world. If the world is already populated with individuals pre-given by transcendental principles, then technical objects like the Internet of Things could only ever report back on these objects to greater or lesser degrees of accuracy. This does little to grasp the ontological specificity of technical sensing, which for its part is figured as operating *on* reality, rather than being a part of it.

Perhaps we can disabuse this notion of the separation of technical sensing from reality by looking more closely at sensing, and at IoT sensing in particular, which already challenges these classical forms by making claims on the production of new forms of sense in the act of sensing. Firstly, in their most basic and generalizable form, sensors have a single function: to transform one type of energy into another. When sensors are spoken of today, that energy transformation is almost always from a type (or types) of physical energy into a type (or types) of electrical energy. For example, and far from exhaustively, common types of physical energy that can be transformed into electrical energy include: mechanical (e.g. length, area, volume, acceleration, pressure, velocity), thermal (e.g. temperature, heat flow, specific heat, entropy), electrical (e.g. voltage, current, frequency, charge, resistance, capacitance), magnetic (e.g. permeability, field intensity, flux density), radiant (e.g. wavelength, refractive index, intensity, reflectance), and chemical (e.g. pH level, composition, concentration, reaction rate, oxidation) (NRC 1995, p. 11). This basic function of energy transformation puts sensors in the broad class of 'transducers'. As a class, transducers also include actuators which, conversely, take electrical energy and transform it into physical energy. Thus: a microphone is a sensor because it transforms physical acoustic energy into electrical waveforms, and a speaker is an actuator because it transforms those electrical waveforms back into acoustic energy. The difference between sensors and actuators, therefore, lies mostly in how they intend to be used (NRC 1995, p. 11). The difference between sensors and actuators will become more important in Chapter 5. For now, the fact that sensing relies on an operation of transformation is important for reconsidering that transformation as something more than making-intelligible, and as being based in something other than pre-given principles.

Take, for example, the measurement of temperature. In the late 19th century, it was discovered that electrical conductors have a tendency to increase their resistance as their temperature increases (Siemens 1871). Resistance thermometers, as they are now called, can accurately express temperature change to precise degrees as a result of the reliable way in which certain metals contract and expand when exposed to heat (Rai 2007). In this instance, the physical energy of the metal contraction/expansion is transformed into another type of physical energy, which is made intelligible by a final interface; for instance, the expansion of mercury within a glass tube will rest at a corresponding degree. Many other kind of temperature sensors — such as thermocouples, which measure the voltage between two wires, or bi-metal thermometers, whose spring will contract and relax as it heats and cools — each measure heat as a process of continuous material variation, which is only afterwards captured as a unit of measurement. Modern temperature sensors involve more processes of transformation before the final measurand is made intelligible. In IoT systems, the data collected by the sensor must then be processed in a way that can be read by a microcontroller, which then must be "packetized" for the specific IoT system, usually using IPv6 (Internet) protocols. This is then rendered according to the system's arbitrary parameters and objectives, and ultimately presented through an interface. Sense data is thus already implicated in a long line of heterogeneous and overlapping processes, all of which are of deep interest to the electrical engineer. Yet they do not feature in the common concept of sensing because, while actively involved in the production of usable data, they have little connection with how that data might be used. Aside from initial concerns over privacy, for instance, the COVIDSafe app aroused very little discussion around how its sense data would be technically generated. The presumption, echoed by Kristina Keneally and others, is that the sense data is already out there; the role of the technology is to reap it in a meaningful way.

My concern here is that the transformative capacities of sensing technologies are poorly grasped in accounts that focus principally on their effects, or are based on the presumption that both sensors, and what is sensed, are pre-given entities. Fortunately, there are recent social scientific tendencies of which we might avail ourselves in the effort to move beyond this narrow focus on the effects of sensing networks, to the detriment of their operations. Significantly, the theories and tools that have recently developed for rethinking sensing have explicitly rejected or questioned the assumption that sensing can and should be understood as such. Rodaway's ethnographic studies, for instance, position the sensory realm as "both a reaching out to the world as a source of information and an understanding of that world so gathered" (Rodaway 1994, p. 5). Vannini, Waskul and Gottschalk inaugurate "sense studies" as a joint sociological and anthropological approach to the senses without the classical dualism between the sensing subject and the sensed object (Vannini, Waskul & Gottschalk 2013). Sensory ethnography, which integrates the "multisensory realm" as well as "experience, perception, knowing and practice" more broadly into critical research, challenges the adequacy of traditional modes of knowing and the way in which social science can be represented (Pink 2009, p. 154). And more recent research has focused on how the "sensorial litter" which interrupts and disorients the researcher can itself reveal what would otherwise be hidden in research not attuned to the senses, and is especially evident in digital interactions and interfaces (Hare 2020). In these accounts, the transformation of the sensory world into an intelligible form is far from a predetermined practice of revealing the real, and exceeds the narrow function of intelligibility that is commonly ascribed to it.

Of the most contemporary research into non-human sensing practices is the substantial body of work produced by Jennifer Gabrys. Gabrys's history of investigating sensing technologies focuses on conceptualizing the new political possibilities and ramifications that arrive with extensive sensor networks and their attendant human-and-non-human ensembles. She argues that sensors can make it seem like the process and problem of perception is "settled", and all that is left is to "report back" on the various moments they encounter and relay (Gabrys 2016a, p. 105). Yet clearly, sensing technologies are already involved in producing new kinds of sensibilities that, while instrumental in certain contexts, are not inherently settled. Climate scientists, for example, use the bioindication properties of lichens to produce new climate change sensibilities, which can help track environmental pollution (Gabrys 2018). Moss (Gabrys 2012), air pollution (Gabrys 2016a), and micro plastics (Gabrys 2013) have all similarly been used as extended sensor networks. Gabrys's argument is that approaching non-humans as sensing subjects in their own right make it possible to "query the promised effects that sensors are meant to have and to test the forms of political engagement that take hold" (Gabrys 2020, p. 14). Gabrys's work takes seriously the question of what sensing technically entails in order to show how the technical is already implicated in established processes of decision making. For her, the problem of intelligibility is expressed in the way that events and environments come to be “matters of concern” in social, scientific, and economic deliberation, pushing the traditional boundaries of sensing as an operation that simply represents a given state (Gabrys 2016a).

Speaking of the Internet of Things in particular, Gabrys argues that the “projected rise in computational objects and applications” that the IoT inaugurates will increase “the registers, materialities, and environments in and through which we access and experience computation”, thereby introducing entirely as many new questions and problems as it is put to work to solve (Gabrys 2016b). When brought into the purview of IoT sensor networks, the myriad problems posed by environmental change (and, usually, degradation) can be understood, acted upon, and controlled as “computational infrastructures and processes” (Gabrys 2016b), which requires the generation of enormous quantities of sense data. Gabrys points out that this generation of data — and the extensive layer of computing devices, infrastructures, and monitoring practices that accompany it — generates a new set of problems regarding the mass distribution of relations, materialities, and effects enabled by the IoT’s “re- thingification” of the world. Electronic waste is one such avenue for exploring the thing-ness of IoT systems, in the ways that the Internet of Things is set upon the problem of waste by being deployed to track the ways in which waste is produced and resources are allocated, as well as in the ways that the Internet of Things itself generates enormous amounts of waste, both at the level of the device as well as on the grander scale of electricity use and resource mining. Critically analysing the new forms of trash, sediment, rust, leakage, residue and sedimentation that IoT systems generate (and sense) enables a new understanding of how sensors, their data, their wider technical ensembles, and those who interact with them are not totally distinct entities, but implicated in reciprocal processes of "thing-ness" (Gabrys 2016b).

Despite the weight given to sensor networks in making social life more intelligible, this section has outlined how intelligibility is a poor concept for encapsulating the technical operation of sensing and the myriad processes that it can ignite. Intelligibility is ultimately human-centric, and invariably places models of human perception as the standard against which sensors (and other technical objects) are judged. As demonstrated above, sensors are increasingly integrated into their wider ensembles, drawing on and enabling technical operations, human gestures, and environmental processes. Intelligibility has, unfortunately, been narrowly used to designate the ability of sensors to synthesize all those realms into an instrumentalizable effect. To move beyond this reduction of sensing, then, an understanding of sensing as an operation of *integration* might better indicate the operation of sensing in accordance with its technical reality.

4.2 Milieu

I have been seeking to displace the emphasis on intelligibility and the concerns with which it is associated: that is, to whom are sensors intelligible? How can intelligible sense data be used? How can we make objects and their environments more intelligible? In this section, I will instead consider the technical operations that constitute sensing, and will focus on the ways in which these operations are motivated by *integration*. Specifically, I will be considering the paradigm of “smart sensing”, a well-established paradigm for designing and operating sensor arrays that is often, if not always, employed in IoT systems. A close inspection of smart sensing will reveal that the presumptions of sensing as an act of making objects and environments more intelligible cannot hold if these entities are assumed to be entirely ontologically distinct. To aid in this discussion is Simondon’s concept of the milieu, and his more specific concept of the associated milieu, which outlines the ways in which technical individuals are not only tied to their environments, but in fact help to generate them.

One of the fundamental elements of sensing that moves beyond the concerns of intelligibility, as outlined in the previous section, is the implication of multiple entities in a physical transformation. Copper springs, for example, contract with the passing of heat, their contraction is registered by a potentiometer, which transforms the physical resistance into an electrical current, which is then parsed by a signal modulator into an appropriate waveform, which is then transformed again for a digital display, and so on. Thus, if sensors can claim to make sense data intelligible by virtue of their ability to represent the changes that occur within an environment, they can only do this with the cooperation and co- genesis of various internal and external forces. Furthermore, what a sensor can claim to represent — be it temperature, acceleration, gaseous dispersion, or so on — cannot be entirely pre-given. If sensing *is* transformation, as I have been outlining, then the sensing array is necessarily implicated in both the sensations of the environment as well as the resulting recordings. Therefore, sensing is fundamentally a process based on the *integration* of various individuative forces.

"Milieu", as Simondon conceptualized it, is based fundamentally on this integrative process. He developed the term in opposition to the way that 'milieu' had been historically and generically used to designate 'an environment', which implied that milieux are the passive backdrop of the more active goings-on of the individuals residing within them. This is one of the central elements of his rejection of hylomorphism and atomism, those theories that claim to explain the individual by way of abstract principles that operate regardless of any given environment (Simondon 1964). Instead, Simondon suggests that milieux and individuals undergo a mutual genesis: "individuation brings into being not only the individual, but the couple individual-milieu" (Simondon 1992, p. 300). Fundamental to this process of co-individuation is the question of *how*, exactly, technical objects can individuate with their environment. This is a critical question for Simondon, who distinguished between the living and the non-living to clarify (and ultimately, repair) the relationship and "rapport" between human and machine (Simondon 2017, p. xvi). It is also a crucial question for the operation of sensing which, as we have seen, has been characteristically understood via a human-centric model of perception and intelligibility. Thus, a distinction between living and nonliving relations to the milieu — in this case, the distinction between perception and sensing — is first necessary before considering how sensing and the milieu operate within an IoT system.

Simondon develops a theory of perception as a mode of individuation that is unique to the living. As Scott (2014) puts it, perception for Simondon functions in "dual registers, both as an operation of individuation of the individual who perceives, and of the thing perceived" (Scott 2014, p. 45). Due to this dual movement in the living being and its milieu, perception is not merely an instance of "decoding" what is given in an environment, but an active articulation of the relations present within its milieu (Lapworth 2016, p. 105). To recall Simondon's example of eyesight, vision occurs when the eye actively solves the problem of light hitting the optical nerve, and creates a resolution (3D vision) that exceeds the initial relation (Simondon 2020). All forms of perception function in this same manner, arising from a problematic relation within the milieu and transforming both the living being and the internal and external milieu (the strained eye that now must wear glasses). Perception, therefore, is an integral part of the individuation of the living, because it *articulates* the living being's relation to a milieu, as well as the relations contained and emerging within that milieu.

Non-living individuals, in contrast, cannot modify themselves in order to articulate or solve the problems of their milieu as perception does. They can, however, modify their *relation* to the milieu, in what can be thought of as an operation of sensing. Simondon gives the example of the traction engine, an early steam-powered engine often used in trains. A traction engine has the task of pulling a train along its tracks so that it maintains as constant a speed as possible, going from a "dead stop to full speed", then diminishing and increasing its speed by degrees as it "hauls the train up rails, around corners, and down slopes" (Simondon 1980, p. 55). As the engine encounters resistance, such as snow or wind, it must adapt and change accordingly, at the very intersection between the technical ensemble of the train and the changing environment. The traction engine

> applies electrical energy to a geographically varied world, translating it technically in response to the profile of the railway track, the varying resistance of the wind, and to the resistance provided by snow which the engine pushes ahead and shoves aside (Simondon 1980, p. 55).

In this respect, a traction engine does not 'perceive' the railway track, wind resistance, or piles of snow, as it does not (and cannot) transform its internal structure (the length of its drive shaft, the plasticity of its external casing, the arrangement of its gears) to accommodate the problems introduced by the milieu. It can, however, transform its relation to these problems by 'sensing' them; that is, by translating these geographical resistances into the differential generation of steam and heat.

For Simondon, the traction engine exemplifies the fact that “the technical object stands at the point where two environments come together“ (Simondon 1980, p. 54). Sensor networks are perhaps an even better example of this dynamic. A watering network in a forest, for example, can turn itself off or on depending on the sensed level of moisture; that is, it changes according to the relation between the moisture probe and the water molecules in the soil. In emphasizing this junction between technical individuation and geographical or ‘natural’ individuation, the perceptual capacities of the living — which would articulate this junction both externally and internally — can be distinguished from the sensing capacities of the non-living — which can only articulate this junction through external relations. Yet, importantly for Simondon, this does not mean that technical objects are somehow lesser than living beings. Rather, this is precisely how technical objects are sustained: “the existence of the technical object is sustained by a double relationship — a relationship with its geographic environment on the one hand, and with its technical environment on the other” (Simondon 1980, p. 54). This double relationship, articulated and mediated by the operation of sensing, is how two otherwise incompatible and heterogeneous worlds can come into communication; through the technical object, “two worlds act on one another” (Simondon 1980, p. 56).

The extent to which the natural and technical environment interact is, however, dependent upon the technical object in question. At this point, Simondon introduces the concept of the “associated milieu” to distinguish technical objects that ‘sense’ the milieu in their operation, and those that directly integrate the physical environment in order to function. As opposed to a milieu, which mediates and is mediated by all technical objects, an associated milieu is “that through which the technical object conditions itself in its functioning” (Simondon 2017, p. 59). A “factory engine”, for example, functions according to the permanent supply of three-phase power, which (at the time of Simondon’s writing) could only be reliably supplied within the controlled environment of the factory (Simondon 1980, p. 57). In one of Simondon’s more famous examples, which we will return to later, he describes the Guimbal turbine, which functions by integrating the natural cooling properties of water with the heating properties of the oil to power an engine (Simondon 2017, pp. 59-60). Distinguishing technical objects that adapt to the milieu from those that *integrate* it was important for Simondon in a number of respects, firstly as part of his rejigging of traditional accounts of taxonomies of technical objects, and problematizing classical notions of ‘progress’ that follow from generalist accounts of technicity. The associated milieu also marks an important point of difference with the notion of invention, which will be discussed in the following section. For now, it reveals the extent to which the operation of sensing already exceeds the simple transformation of the unknown into the intelligible.

In the case of the genesis of the Internet of Things, sensing has continued to employ systems that rely on adaptation — resistance thermometers, for instance, adapt to their milieu by modulating the relation of a capacitive metal to the kinetic energy of atoms — but has also evolved increasingly towards integration. Smart sensing, a catch-all term for sensors given the additional capabilities of a microprocessor (Spencer Jr, Ruiz-Sandoval, & Kurata 2004), is oriented towards greater integration with other physical and digital processes to generate faster, cheaper, and more energy efficient processes and more accurate and widely deployable ends. Smart sensing refers to the simultaneity of sensing with other computing processes in order to put sense data into specific and changing contexts. Similar to the use of the term "smart" in relation to communication, as discussed in Chapter 3, smart sensing is based on an increase in heterogeneity; the "promise" of smart sensing "relies on robust sensing of diverse environmental facets" (Laput, Zhang & Harrison 2017, p. 3986). Specifically, smart sensing involves a number of elements, including a sensor, a signal processor and a communication interface for translating the sensor's signals into the wider computing array (Song & Lee 2008, p. 11). Smart sensing has been defined as a type of sensing that "provides functions beyond those necessary for generating a correct representation of a sensed or controlled quantity" (Song & Lee 2008, p. 12). Achieving those functions requires physically and operationally integrating sensors into the wider technological array. Sensors must become significantly smaller, have lower energy needs, be low cost, secure, physically resilient, and able to communicate in real-time in order to integrate into the wider sensing array, which includes software, communication protocols, and physical materials on the motherboard (Potyralio 2016, p. 11880). Smart sensing — which is increasingly, if not universally, now being implemented in IoT systems — requires that the sensor integrates with a number of other heterogeneous elements both internal and external to the technical ensemble.

In this respect, the evolution of sensing towards "smartness" is indicative of sensing's technical basis in forms of integration, and the necessary co-genesis of technical elements and their milieu. In the 1995 publication by the National Research Centre, “smart sensing” was defined as a technique of sensor design in which the complexities of sensing are “concealed internally… such that the complexity is borne by the sensor and not by the central signal processing system” (NRC 1995, p. 15). To accommodate this increased complexity and still maintain reliability and accuracy, it was said that a smart sensor system must have

> dedicated “on-chip” signal processing. Realization of this concept simply means that electronic (or optical) signal processing hardware is dedicated to each sensor and miniaturized to the point that it becomes part of the sensor package (NRC 1995, p. 15).

In other words, smart sensing requires the sensor ensemble to “bear the complexity” of the technical operation by integrating various technical elements into the ensemble to the point where it can realize multiple transformations. Since this publication, the accepted definition of smart sensing has barely changed, having been merely refined somewhat to specifically mention the computational processing required

> a smart sensor is the combination of a sensing element with processing capabilities provided by a microprocessor. That is, smart sensors are basic sensing elements with embedded intelligence (Hunter et al 2010, p. 29).

Most importantly, the ability of a smart sensing array to integrate into its environment, and to be self-sufficient within that environment, has become more crucial, especially in industrial contexts. In a publication on the basic technological requirements for the development of Industry 4.0, the authors defined an “ideal” smart sensor as such:

> The smart sensor measures multiple components, is self-calibrating and self-optimizing. It is easy to be integrated in the process environment — with regard to process connections and communication connectivity — and maintains its operation autonomously. … It possesses process intelligence and can generate information from multi-sensor and multi- dimensional data (Eifert et al 2020, p. 2038).

Thus, unlike more rudimentary forms of sensing, which may simply relay a sense data input through a signal modulator into a digital output, smart sensing involves the processing of that data before it exits the sensing array, either to another data processor or immediately into a digital interface. This data processing is computational, happening “at a higher abstraction level for decision making”, possibly involving more complex data processing techniques like “data mining and machine learning algorithms and models” (Ghayvat et al 2015, p. 34). Processing data within the sensor array has a number of benefits, reducing latency, improving energy efficiency, and protecting data privacy (Pagliari & Poncino 2020). Thus, even in the realm of technical discourse, sensing implies a significantly more sophisticated process than the reductivist intelligibility-oriented account allows, given that intelligibility positions technology as arriving after a pre-given sensation, rather than as a relational reality that arises in its relating.

There is a question, however, hanging over the status of integration in so-called smart sensing. Could a smart sensor be said to integrate a physical environment into its functioning in the way that a Guimbal turbine integrates oil and water into its rotation? In other words, do smart sensors generate associated milieux? And if so, what does this imply about the way in which sense data comes to be instrumentalized, and the claims that can be made on its behalf? The next and final section in this chapter will address this question by referring to Simondon's concept of 'concretization' — the process by which technical objects evolve by merit of their integrative capacities. By remaining mindful of the variations in sensing ensembles, their specific capacities — and instrumentalizations — can be more accurately understood.

4.3 Concretization

Having reframed sensing in terms of its individuating operations, it is now possible to address the question of IoT sensing more specifically. What, beyond the prejudices set out by representationalism, might we say about the manner in which it is instrumentalized? The first section in this chapter argued that the alignment of sensing with human perception produces a scenario where the utility and ontology of sensing is made equivalent to its ability to produce intelligibility. The second section argued that the technical operation of sensing ultimately has very little to do with intelligibility, and that the ability of sensing to 'tap into' environments is in fact one of its constitutive functions; the operation of sensing literally integrates with an environment in order to individuate. Thus, so far, we have reconceptualised sensing from an operation concerned primarily with representing the world in such a way as to make it intelligible — that is, as a set of objects — into an ongoing process of individuation. What now needs to be addressed is sensing's mode of instrumentality. In this section I will argue that the instrumentalization of IoT sensing relies on its ability to integrate individuals and environments in order to produce and maintain an associated milieu, and to do so in such a way that the sensor becomes self-sufficient and pluri-functional. In other words, the instrumentalization of sensing relies on its ability to *concretize*.

Understanding concretization requires stepping back to one of Simondon's principal ontological stakes: that technical objects must be understood, he argues, by their capacity for genesis. Technical objects are not defined by “this or that [object] given in time and space”, but by “the fact that there is a succession, a continuity that runs through the first [object of its kind] to those we currently know and which are still evolving” (Simondon 2017, p. 26). It is impossible, in other words, to understand the technical reality of a semiconductor or an engine without understanding it as part of an evolutionary line of objects that have the capacity to further evolve. A semiconductor cannot be understood apart from the actual and potential evolution of transistors, and car engines cannot be understood apart from the actual and potential evolution of combustion. Therefore, a given technical object — that is, “a definite stage of evolution” — already contains within it “dynamic structures and schemas” that “partake in the principal stages of an evolution of forms” (Simondon 2017, p. 26). In other words, to understand technical objects as capable of genesis is to understand each singular object as containing within it a structure (or structures) that has propelled it into its current state, and can potentially propel it into a new form.

Concretization is Simondon’s term for this genesis. Specifically, concretization names the evolution of a technical object towards a functionality that is more internally coherent and integrated. As a technical object concretizes, “its internal coherence increases and its functioning system becomes closed by becoming organized” (Simondon 1980, p. 47). The concretized object’s milieu is dynamically incorporated into its functioning, influencing and regulating it, “which makes it possible for the conditions of functioning to be self-sustaining” (Simondon 1980, p. 48). In other words, concretization names the process by which technologies undergo an "increasing convergence and integration of heterogeneous elements and forces into self-sufficient modes of interoperability" (Simondon 1980, p. 31).

To make sense of this somewhat complicated sentence, Simondon provides a number of examples. One of Simondon's more frequently cited examples of concretization is, again, the Guimbal turbine, which mixes oil and water within its cavity in order to realize two essential functions: the powering of the turbine (with the energetic potential of the oil) and the cooling of its parts (with the water). As well as being the basis by which an associated milieu is generated, Simondon describes this pluri-functionality of both oil and water as an example of the technical ensemble *concretizing*; that is, integrating its own internal functions in order to achieve a new function and produce a new level of reality. More significantly, he argues that the pluri-functionality of the oil "*is* the very schema of concretization that makes the invention exist, as a regime of functioning" (Simondon 2009a, p. 19, my emphasis). Concretization thus is not merely an explanation for technical progress that can be applied retrospectively, but is rather the mode of a technical object's existence. Furthermore, technical objects that integrate different kinds of realities cannot be understood without recourse to the way in which potential structures their evolution.

Still the operation of concretization requires more parsing. Perhaps more easily understood than the Guimbal turbine is the difference between two other examples of technical genesis; one which tends toward concretization, and one which diverges away from it. Simondon's example in this respect is the difference between an airplane and a flower grown in a greenhouse (Simondon 1980, p. 47). Both examples represent different modes of the genesis of industrialization: international flight and the distribution of intensively bred flowering species both rely on advanced material networks and processes which are themselves intensely heterogeneous and self-sufficient to a degree. The airplane has evolved to become more internally coherent by increasingly resembling hollow bird bones; the ensemble of the airplane has concretized to become a more internally complete system. A greenhouse flower, on the other hand, is increasingly fractured from its own modes of integration with the milieu. It has been bred to display particular qualities in such a way that it cannot reproduce on its own, requires an extremely specific environment, and depends upon humans to control its reproduction. Those external elements of the milieu which were integrated in the airplane are instead further externalised in the greenhouse flower; "the artificial regulations of the greenhouse replace what originally were the object's natural regulations" (Simondon 1980, p. 48). Though equally technical, in comparison to the airplane its functions are separate and abstract; in order to survive, the greenhouse flower requires extensive external regulation (a trellis to support its heavy flower heads; a human hand for pollinating; a graft onto a hardier rootstock; and so on). It is worth detouring into airplanes and greenhouses to better understand the level of concretization that is involved in a given IoT system, and specifically as concretization relates to sensing. To put it another way: does smart sensing tend towards airplanes or flowers?

Understanding the relative tendency of smart sensing towards or away from concretization requires careful consideration of the effect of the ‘smart’ on the integrative operation of sensing. On one hand, IoT systems have been designed to be self-sufficient, automatic, and increasingly coherent with their environment in a way that remains open to it. On the other hand, IoT systems have also been designed in such a way that requires human intervention at critical points. These points are, largely, the points at which the digital interface appears; an IoT sensor network requires physical transducers as much as it requires a human to assess and respond to the transducer’s inputs, for purposes of maintenance as much as operation. Montoya (2019) makes this case against the ability to apply Simondonian ontology to digital objects, arguing that concretization is too based in the analog to apply to digital objects, of which the microprocessor attached to a sensor would be one example. As he rightly points out, digital devices — which rely on binary computations — do not rely exclusively on internal physical coherence in order to solve issues of incompatibility (Montoya 2019, p. 719). Essentially, Montoya claims that the integration of the technical regime and a milieu that accompanies analog objects — that is to say, the disparation that would put them into communication — does not feature in digital objects past a particular, elementary point. A GPS device in a car will evolve digitally a hundred times over, and in ways that paradigmatically affect its functioning, without its material elements facing any new kind of incompatibility. The issue that Montoya ultimately attempts to address is the problem of whether a technical object can be said to be *open* or *closed* to the invention of new structures.

Simondon distinguishes between the open and closed technical object according partly to their materiality, and partly according to their relative indeterminacy. A closed technical object is one that is

> completely constituted by the moment it is ready to be sold; from that moment of greatest possible perfection, the object cannot be but used, degraded, making it lose its qualities until the final dismantling and return to the state of separate parts (Simondon 2014, cited in Montoya 2019, p. 723).

An open technical object, on the other hand, is to some extent "always in a state of construction" (Simondon 2014, cited in Montoya 2019, p. 723). According to Montoya's reading of Simondon, digital devices and systems are necessarily closed; a smartphone, for instance, arrives "completely constituted" but able to be disassembled into "separate parts" (despite commercial and physical interventions that prevent consumers from opening their phones). By the same logic, IoT systems would also be considered largely closed systems, made up of multiple layers of replaceable parts, arriving as complete systems of communication, sensing, and actuation, impenetrable to the production of new structures that would allow it to truly "evolve". Such a determination, however, would have to ignore the material transformations induced by the operation of sensing, and the material transformations that are necessary for IoT networks to adapt to unpredictable and changing environments. Thus, while Montoya's critique points to a critical question regarding the nature of progress in technical objects that reside in digital operations, it cannot be applied to digital systems, such as IoT sensor networks, as a whole. The critical point here is that the operation of sensing provides an IoT system with a margin of indeterminacy that maintains its openness, and is also *the point at which sensing itself occurs*.

Sensing requires an irreducible relationship between technical and natural worlds, and sensing itself is impossible without the integration of these heterogeneous regimes. This irreducibility is not entirely *lost* at the level of an IoT system, as Montoya implies; in fact, irreducibility is increasingly *required* in IoT systems to achieve overall functionality. This is made especially clear by the fact that modern IoT systems are overwhelmingly “service-oriented” (Li, Da Xu & Zhao 2015). Service-oriented IoT applications are designed to offer a contextual suite of actions, which are based on the specificities of a given milieu. Services themselves are platform-agnostic computational elements that perform functions ranging from simple requests to complicated processes (Papazoglou 2003). To carry out a service in an IoT system, a variety of elements (application logic, sensors, transmitters, actuators, and so on) need to be coordinated to achieve the predefined service function. Each of these elements belong to a particular architectural layer; each IoT system could potentially have its own unique set of layers, though the typical layout is sectioned into three parts: the sensing/perception/data collection layer, the network layer, and the application layer. Smart sensing plays a critical role in this process, providing the capacity to *integrate* core operations — data collection, transmission, and processing being the most crucial — so that a service, often required in real-time, can execute according to a specific environment (Chi et al 2014, p. 1418). For example, a water quality monitoring system that measures light, CO2 levels, water turbidity and water temperature relies on a number of less technically essential integrations, such as the integration of discrete sensors in a single node (in this case, achieved by a flotation device that keeps the light and CO2 sensors above water, and the temperature and turbidity sensors below), the integration of heterogeneous data-translating services (analog-to-digital signal transmission must converge with digital signal processing to retain a small motherboard arrangement), and the integration of wireless transmitter protocols with the power source to remain energy efficient (Chi et al 2014, p. 1423). Yet the most technically essential integration — that is, the integration that is most concretized — is the integration required *at the point of sensing*: light, water, suspended solid particles, and the turbidimeter converge to produce a certain diffraction index (Haven, Terault & Schenken 1994, pp. 128-129). Integration, in this sense, is a structure that is propagated by the operation of sensing, and is itself the conditions under which sensing takes place. Viewed from the point of view of integration and indeterminacy, the operation of sensing can thus be understood as *that which retains the margin of indeterminacy* in an IoT system, and as that which operates precisely within that margin.

The question posed at the end of the previous section — is smart sensing integrative? — can now be answered with more precision. In the example of the Guimbal turbine, the natural and technical worlds are integrated in the individuation of the turbine itself, at the very junction of their meeting. Smart sensing at first appears to be lacking this integrative ability, as it appears closed to any ontological junction between the natural forces it records and the technical elements that capture them. However, when a specific smart sensing system is examined more closely, what can be observed is various tendencies towards concretization, rather than ideal cases or absolute instances. "Technical objects tend toward concretization, whereas natural objects, such as living beings, are concrete to begin with", Simondon argues (Simondon 2017, p. 51). Approaching smart sensing with this level of sensitivity thus makes it possible to attend to the *instrumentalization* of sensing with more specificity. If sensing is an individuative process tending towards concretization, this brings into question the individuated terms that are produced along with it. That is, what does sense data now signify, if not (or not only) a representation of a state of affairs?

The data generated by the transformative integration of sensing is also a part of its concretization. It is helpful to remember the new understanding of information discussed in Chapter 3, as a process of in-forming based in the meeting of disparates. As Iliadis argues, it is not that concretization is a layer added to a technical object; it is "concrétisation all the way down" (Iliadis 2013, p. 15). Concretization is "the engine that drives individuation", and information is "the gas" (Iliadis 2013, p. 16). What appears later as sense data in the sensor ensemble is thus "the gas", as it were, that enables the sensor to integrate and become increasingly interoperable. The proceeds of sensing — which include sense data but are not entirely reducible to it — are therefore not merely bare representations of a pre-given environment, but are also the effects of an ongoing process of the technical object emerging into its own reality. What is sensed is not merely the transformations of the world which the IoT claims to have captured but, at least as significantly, the sensing array and its unique transformations. Under a schema of concretization, we could therefore understand the production of intelligibility (to greater or lesser degrees) as a side-effect of the concretization of a sensor ensemble.

From this point of view, the meaning and function of sense data loses the reductive self-evidence attributed to it by a representational account of the Internet of Things. Sense data is instrumentalized in a way that is not purely representational, but rather is based on its ongoing integration with heterogeneous orders of reality. In the same way that connectivity is opened up to heterogeneity in Chapter 3, the instrumentalization and intelligibility of sense data is here opened up to integration and individuation. This, however, is not to negate the ways in which sense data can ossify relations as a product of this integration. In fact, the stabilization of these relations is a necessary mode of the sensor network's functioning. Sensing, as a technical operation directed at concretizing the relation between the technical object and the milieu into its functioning, produces sense data at the point at which this relationship is stabilized.

In sum, the basis of the technical reality of sensing, as well as involving transformation, lies also in the integration of sensors into their surroundings — and in fact, relies on this integration to function. This fundamentally troubles the presumptions of intelligibility, denying the human as its basis and questioning the straightforward causal relation it implies. The evolution of IoT sensor networks especially highlights this tendency of sensor networks to evolve and function on the basis of becoming more interoperable with the environment, rather than becoming more representative of it. Simondon's concept of concretization explains this process by which technical objects evolve, opening the technical object (here, the sensing array) to the call of other individuative forces, and placing its genesis and essence within their cooperation. In reframing sensing within concretization, my aim is not to claim that smart sensing is a perfect or ideal instance of concretization. Rather, my argument is that IoT systems can be approached as tending towards concretization, especially in the ways in which its sensing ensembles operate.

Sensing and its resulting data can then be approached from the perspective of an ongoing operation of integration, requiring both heterogeneity and stability. Sensing is no longer only a process of re-presenting an environmental event, but an integrative operation residing within the margin of indeterminacy, instigating the individuation of various elements within a technical ensemble and associated milieu, in order to come into its own regime of functioning. The data produced by sensing is one of the side effects of this process; it does not represent a pre- existing reality that was there to be discovered, but rather is one of the elements that helps bring that reality into being. If, in this formulation, the presumptions of intelligibility seem to fall by the wayside, my contention is not that intelligibility disappears in sensing. It is, rather, a question of intelligibility being understood as more than the reproduction of an existing phenomenon.

Concretization, expressing both the way in which a technical object evolves, as well as the schemas that enable it to do so, provides a ripe concept for examining and better understanding the ways in which human-technical ensembles participate in intelligibility, but are not necessarily incumbent to it. Claim II will explore this in more detail, looking to three different individual-milieu couples and the ways in which intelligibility, when it emerges, operates as a mode of integration. First, Tom's farm reappears under the guise of the livestock draughter, and its reintegration of what has been sensed into a coming milieu. Next, Dave Keightley's BRIM system transforms a smart building into a living organ, reintegrating natural structures into the sensor network. Finally, a walk within Canberra's National Arboretum questions how exactly 'a forest' becomes intelligible. Without our re-formed concept of communication, and the attention to disparation, metastability, and materiality that this involves, our reading of these three ensembles would be quite different; perhaps more critical and actionable towards a social good (or some other predetermined end), but also perhaps less attendant to the real forces of transformation at work in each.

Claim II

The Organs

In the previous chapter, I examined the tendency for the operation of sensing to be reduced to the problem of intelligibility, with which a certain image of both knowledge and control are associated. I suggested that sensing is characteristically made intelligible in terms of its likeness to human perception and I troubled the notion that intelligibility is necessarily the goal of sensing. I argued that the operation of sensing is better understood in terms of the integration of different layers of reality via sensing's essentially transformative capacities. The concept of concretization, I suggested, helps to undo the grasp of intelligibility on sensors, sense data and entire sensor networks, enough to consider the tendencies of technical individuals towards greater integration. It is not so much that intelligibility disappears from sensing once viewed from the perspective of concretization, but rather that it is not given ontological privilege. In line with the discussion in Chapter 3, we could say that sensing is not so much about producing information, but a process of in-forming which enrols the individual and its milieu. Importantly, sensing is not the only site at which concretization happens; rather, as an operation that functions by merit of its integration of different layers of reality, it is an essential example of the kind of in-forming that is required in order for a technical object to persist, progress and orient itself with its environment.

As we saw at the end of the chapter, this has significant implications for the notion of technological progress and the ways in which we might measure it. Specifically, the connection between intelligibility and intelligence is neither direct nor meaningful. Again, this is not to claim that intelligence does not or cannot exist to varying degrees in technical systems or objects. Rather, the claim that technology progresses as it increases its ability to represent the world becomes unsustainable. Indeed, the Internet of Things is a particularly good example of a technical ensemble that has progressed on the basis of its increasing ability to make itself interoperable, with intelligibility as a necessary but not central side effect of that interoperability. Sensing, particularly smart sensing, is a critical means by which an IoT system achieves its interoperability — not necessarily with other technical objects, which are often blocked from inter- operation by privatised software and protocols, but certainly with the milieux in which it must operate. Importantly, however, this interoperability is never 'perfect' nor 'complete'. As an ensemble of technical elements and individuals, a smart sensing system requires both a level of indeterminacy — achieved by sensors themselves, which transform and in-form on the basis of the indeterminate — as well as a tendency towards internal coherence and individualisation — achieved by the wider ensemble, which integrates these transformations.

With this in mind, the question of sensing and intelligibility requires some further exploration. Rather than dismiss those attempts to progress sensor technology via its ability to generate and act on intelligible data, I propose an alternative way to approach sensor networks, as ensembles that maintain a critical tension between openness and closure (between the margin of indeterminacy and the tendency towards individualisation) and this, contrary to the representational account, is what generates its 'smartness'. To pursue this line of argument, I will discuss a smart building sensor network system called BRIM, developed by a small start-up company in Canberra, Australia. First, the BRIM system will be described at the level of its basic functions, its hierarchy and the major directions that its designer, Dave Keightley, and his employees have conceived over the years of its development. Some initial preoccupations, hesitations and enthusiasms regarding BRIM's potentials will be discussed. Then, with an eye to opening up BRIM's potentiality — and specifically, its intelligence — to a more processual reading, I will turn to a thought experiment from inventor Nikola Tesla, that I term the 'perfect brain', to reconsider the relationship between automation and intelligence in BRIM.

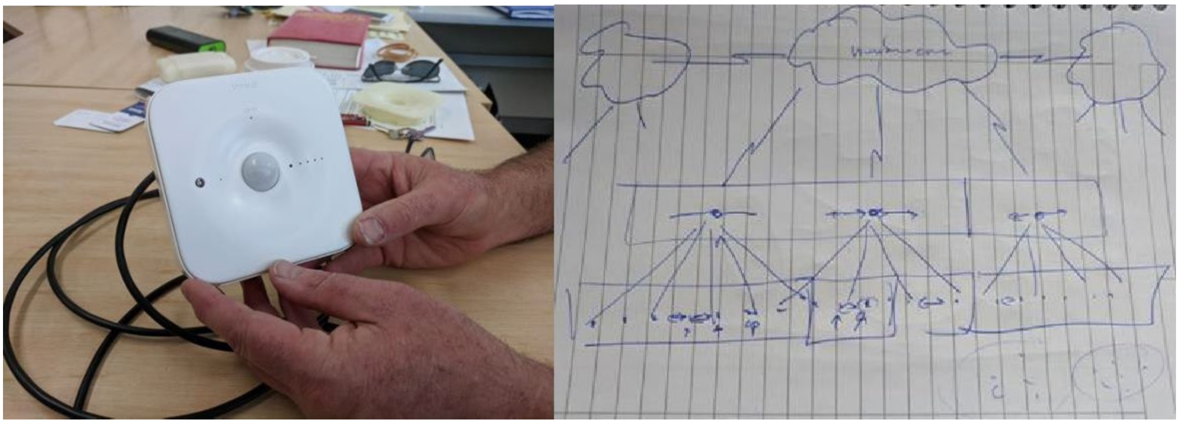
BRIM

"It was like that moment in Space Odyssey 2001", David Keightley began a little breathlessly, "where he lands on Jupiter and goes, *my god, it's full of stars*."

David is sitting with me in a small conference room, a simple white table between us. His office and centre of operations are just outside the door, next to a kitchenette and around the corner from another small business which co-shares the second floor. He was talking about BRIM, a smart building sensor network he invented, which is the flagship of his company, Ecospectral. In 2021, BRIM has been rebranded as eBRIM and is being sold largely as an energy efficiency tool, designed to modulate power use and load according to an occupant's unique usage and the fluctuations of the wider power grid. Back in 2018, however, the question that was occupying his mind concerned the ramifications of sensor networks on human habits. David described to me how the development of BRIM had changed over the years, from a relatively narrow focus on energy efficiency to a grander vision of influencing and shaping human habits and behaviours:

> The first goal of the system was to minimize energy consumption. To effectively shrink wrap energy consumption around individuals. Then the second [goal] is to basically look out after those people. Make sure they're safe [...] and to understand what's going on with the building. And lastly then, and this is where things start getting interesting, is we discovered that the system can also *modify behaviour*.

With some enthusiasm, David then told me about an experiment he had conducted on his own behaviour. He installed a BRIM network to record his movements within the floor of his office building, which Ecospectral shares with another business, the employees of which he knows well. After two weeks of data collection, David discovered that he was getting up from his desk dozens of times a day. The vast majority of the time his destination was the desk of another employee working on the same floor. He knew that he would often go visit this person to talk, but hadn't realized that, at peak frequency, he was getting up to talk to him every fifteen minutes. This realization led to David drastically reducing how often he left his desk, and he reflected on this near the beginning of our interview:



BRIM sensor node, and David's hand drawing of the BRIM system hierarchy. Images by Author, 2018

> I thought it was interesting that my behaviour was so significantly modified, and two that there was something positive out of that, that ifyou [...] opt in and give a window into your behaviour, you can change behaviour.

BRIM is a system comprised of a mesh network of sensors, which means that each sensor node can "communicate with each other and make decisions based on what's happening nearby". Each node collects sense data — which could include temperature, movement, energy use or sound — and processes it at the level of the node. This data is then sent up to the next 'layer' in the system, which comprises the equipment and software that "interfaces into the network of the building". The communication between the node and the second layer is what allows BRIM to do things like control the building's air conditioning, "control larger pieces of equipment, or whole power circuits". The topmost layer is the cloud, where the processed sense data, resulting decisions, and any other computations are stored, as well as cross-referenced with information sourced from the Internet.

BRIM's software is focused on discovering and correlating particular patterns of sense data in order to correlate sense data with events that happen both inside and outside the building. To address events within the building, David installed four small LEDs in each node, showing colours from red to green. These lights are the point at which the building communicates its own internal state with its occupants:

> And it's got cool LED feedback, there and there, so that's a multicolor LED there, and that's uh 4 LEDs that can flash in patterns. So we keep them off most of the time. But let's just say that the building was to tell you something. This is pretty bright. That little multicolor can tell you something. It can tell you, green, that's a good way to go. Red, don't go that way. So let's say there's a fire, or someone with a gun in the building. So it can tell you – yeah. Don't go there. Go where it's green.

In a more banal example, David explains how the system can also signal when a room is being put under some kind of stressor, notably human stress. Stressors that originate from outside the building could also be responded to:

> You can actually have, at the sensor level, have some indication that there is a world event, a large conflict might have started, an airplane might have crashed in a building, an event that would emotionally affect a wide number of people. You can actually have that awareness at the sensor level to pick up — is there an increased stress here? Is there something I should be aware of?

David imagines that BRIM, if rolled out in cities around the world, could chart how global events affect these buildings and, more importantly, the reactions, movements and habits of people who inhabit them. Climate change was one such global condition that David was especially intent on tracking and responding to. “I think we’re in a little bit of trouble”, he said grimly, imagining the day when all our current energy resources run out. “At that point in time, the buildings themselves have to become so smart that they can react to grid requirements […] whilst keeping the occupants comfortable. It’ll have to be able to react in real time”.

Ultimately, for BRIM to achieve a state of automation that could keep up with the demands of a climate catastrophe its structure needs to become more adaptive. In pursuit of this goal, David has designed and developed the BRIM system in line with the organic metaphor of the nervous system. As it proclaims on the Ecospectral website, “just as you would not classify an animal or human as being smart if they did not possess a nervous system, so it is for buildings. Ecospectral’s BRIM system brings neurology to the built environment.” (Ecospectral 2020). From this perspective, BRIM’s ability to manage behaviour must rest on its ability to attain a level of neural responsiveness.

A sensor network system that is able to react and adapt to a number of layers of operation — occupant, building, neighbourhood, local electricity grid, national power supply — introduces other complications, the biggest being privacy, of which David is well aware. Much of our conversation was spent discussing the possible abuses of privacy, agency and consent that can be easily exploited in IoT systems. He emphasised that BRIM would involve extensive human intervention and interpretation in the collection and analysis of sense data. “The data would be fed to human resources”, he repeatedly reminded me, emphasizing that there would be no algorithm “behind the curtain” making decisions about observed human behaviour. Furthermore, the fact that data processing happens on-node means that no individual data is sent up to any other layers; “we keep it as private as possible...there’s no information on particular individuals.” Human resources would play the most significant role in this scenario, being the point at which any indications about a building’s occupants would be reported:

> So we’ve got an audio sensor now, and if we detect stress, then that’s a human resources issue. … If there’s a stressful situation, we can make changes with temperature, we can make changes with light and other things. To potentially defuse the situation.

This is the point at which concerns over privacy arise in a technical sense: how are voice recordings and physical movements, for example, stored and secured by the network? As David went on to explain, with the installation of microphones and the siphoning of collected sense data to either individuals or authorities (like human resources), the sensor system does have the potential to exact a determining influence: "there's this other part [of the sensing system] which is a little bit frightening, which is, can I change behaviour without telling people that I'm changing their behaviour? … where is the boundary there?"

We could, of course, examine the behaviour management in smart building systems from the point of view of social policy and management. Simeone and Patelli point out that “urban sensing, a set of analytical practices related to the phenomenon of big urban data, is aimed at a further transformation in the processes of knowing — and hence possibly controlling, and actuating — the city" (Simeone & Patelli 2016). Smart precincts, and smart cities in general, are pursued so avidly by governments in part because they promise to make their space "knowable and manageable in real time, sentient in some ways" (Simeone & Patelli 2016). The concerns regarding privacy in distributed sensor networks are well-reported and much discussed in the literature (see Weber 2015; Wachter 2018). This was the "frightening" aspect that David mentioned in the interview. How will these systems be enabled to act, according to the sense data they gather and process? Who will write the programming and maintain the algorithms? What scope will corporations, governments, communities, judiciaries, and individuals have to act on, and intervene in, these automated processes? At what point is the removal of personal freedoms preferable to the consequences of irresponsible energy use? To what requirements are sensor network systems like BRIM, and developers like David, held accountable?

Yet, it is worth questioning whether the anxious focus on automation is the best way to critically analyse the future of wireless and human-technological life. On this, it is worth recalling Simondon's insistence not to begin with pre-given entities, of which "climate change", "privacy", and "building occupants" could qualify. As I have been suggesting, posing sensor networks as pre-given entities inevitably falls in step with those critiques that reduce human beings to pre-given bundles of behaviours, vulnerabilities and malleable desires awaiting technical shaping.

With an eye to shedding new light on the question of automaticity, sensing, and intelligence, it is worth considering BRIM from the angle of its difference to Nikola Tesla's 'perfect brain'. My intent here is to problematize some of the ready-made critiques that might crop up with a conventional account of BRIM's operations, especially around the question of sensor intelligence tending towards 'natural' functions. BRIM has been largely understood through an analogy between intelligent sensor networks and bodily organs and through the idea that it possesses an intelligence that is not entirely human. To explore the technical and operational nuances of BRIM's organ-ic operations, I will now turn to a prophetic interview with Tesla from the early 20th century, wherein he imagines the 'perfect' application of wireless to amount to the invention of a worldwide 'brain'. In comparing Tesla's brain to David's sensory organ, the inadequacy of 'perfection' as 'automation' comes to light, and the operation of sensing as processual integration can be reconceived. In short, by taking the metaphor of the organ more seriously, there can be a more serious consideration of what sensing entails.

Brains

In an interview in 1926 extolling the possibilities of radio technology, American inventor Nikola Tesla prophesied a world freed by a global network of wireless energy and communication. Airplanes powered by radio waves would replace cars. Telephones would shrink to fit in a jacket pocket and Western civilization would be steadily replaced by the much more efficient model of the beehive. Amongst these prophecies, there is a noteworthy phrase that appears halfway through the interview, where Tesla claims:

> When wireless is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, all things being particles of a real and rhythmic whole (Tesla in Kennedy 1926).

The remainder of the interview is a confrontingly prescient dialogue on some of the most significant limitations of technological progress, including its supposedly patriarchal foundations and reflections about what lies on the technological horizon, with Tesla effectively predicting the invention of the mobile phone. Here, I will be limiting my discussion to the initial concept: the ‘perfect’ application of wireless, the ‘huge brain’ that follows, and the ‘particles’ of a ‘real and rhythmic whole’.

The idea of technological perfection is rightly looked on with a baleful eye by sociologists and technologists alike. This is commonly because the concept of technical perfection is construed as an object or system that is able to intervene in the “real and rhythmic whole” in a way that is perfectly determining. 90 or so years after Tesla's wireless prophecy, in the small back room of an office in Canberra, David described to me how BRIM was driven by an oddly similar vision:

> I thought OK so what’s the ideal situation for sensing? What is the most amazing building that you can image? And that is where the building actually becomes a sensory organ… It would react to us moving, and how we move throughout that organ. And I thought, well … I can’t paint the walls and turn them into a sensory organ. But what I can do is imagine painting the wall,

> and then shrinking [it] to the point where I had enough power and enough sensing capability so I had a cost effective atomic unit for sensing. And then as they got cheaper, they'd get more and more ubiquitous… So that's what I was trying to do.

David's image of a huge sensory organ, miniaturized into discrete sensing nodes, aligns remarkably with Tesla's hopeful fantasy. In the perfect application of wireless, all the particles of the rhythmic whole could be reacted to by a ubiquity of sensor particles. In both visions, converting the world (or a building) into an organ requires a level of so-called perfection. In Tesla, this is a matter of installing wireless, imagined as the regular and constantly communicative points of wifi that the more affluent parts of the world experience today. For David, painting the wall with sensors invokes an image of saturation and coverage, a continuous lining within which all is captured and modulated. Crucially, however, capture itself is not sufficient from the BRIM organ; it must also act on these captured sensations, and it must do so autonomously, as a living organ autonomously tastes, digests, sniffs, and listens.

For his part, and against the popular opinion and policy of his time, Simondon rejected the claim that automation is a benchmark for technological progress and human benefit. He argued that:

> Worshippers of the machine commonly present the degree of perfection of a machine as proportional to the degree of automatism… They suppose that by increasing and perfecting automatism one would manage to combine and interconnect all machines among themselves, in such a way as to constitute the machine of all machines (Simondon 2017, p. 17).

In some respects this accords with the image of Tesla's huge brain as a machine of all machines, or the Internet of Things as the tool that will connect the living and non-living machines of the world into a perfectly autonomous whole. However, Simondon points out, automatism is actually “a rather low degree of technical perfection” (Simondon 2017, p. 17). To explain this, Simondon transforms the problem of ‘degrees of perfection’ into degrees of indeterminacy. To equate perfection and automation is, according to Simondon, a technical misunderstanding. Automation appears as perfection because it has the appearance of acting without the need for human intervention. BRIM, for example, was built for automated energy saving. Indeed it is based around executing a number of functions that do not need the direction of a human actor: turning lights on before entering a room, regulating air conditioning according to users’ habits as well as national trends and local weather, putting applications into predictive power saving mode — these are all operations that can be done more quickly, accurately, and with better prediction when the human mediator is absent. It would follow, then, that achieving such types of perfection (for clearly, efficiency is only one of an infinite variety of perfections) is dependent on enabling the technical object to function increasingly independently, in a way that incorporates (senses) the human but does not integrate it into its functioning.

However, following Simondon, I would argue that this is precisely not the case with automation, and especially not the case with BRIM. Simondon is strongly critical of the presumption that automata do not require humans, calling it a “rather elementary enthusiasm” that “forgets” that it is precisely those technologies that are automated “that are most reliant on man*[sic]*” (Simondon 2017, pp. 139-140). BRIM, for instance, requires a living being to do the work of living in order for the system to function. Not only are humans required at the hermeneutic level of delimiting, defining, maintaining and authorising the sense data the system collects — a job which David’s co-workers currently do for smaller installations, but which will need to be done by a team of database managers and administrators of larger organisations — but humans are also required to express habits, inconsistencies and changes in behaviour for the system to track, process, and respond to. Furthermore, BRIM’s AI requires pre-generated ‘use cases’ in order to function. Use cases are essentially data profiles; for example, average vocal frequency range for males, ideal energy usage for a ten square meter space with five computers and so on. Typical use cases are a standard and necessary resource for sensor systems to literally make sense of the data it accrues over time. Human forms are thus required for the sensor node to do its work. A clarification from Simondon, again in terms oddly coincidental with Tesla’s, explains this: “self-regulation in which the whole of the milieu must be taken into account cannot be achieved by the machine alone, even if it is perfectly automated” (Simondon 2017, p. 140, my emphasis). In other words, David’s sensory organ and Tesla’s huge brain require mutual participation from other elements, individuals and ensembles — enabled by the sensor node’s relative margin of indeterminacy — far more than they require automation.

To conclude the conversation between BRIM’s sense organ and Tesla’s perfect brain, I will consider the image of the organ itself. In comparing BRIM to an organ, there is a clear reminiscence of the cybernetic theorization of information in order to integrate technical and living systems on the basis of a biological understanding of stimulus and response. As discussed in Chapter 3, the folly of cybernetics is not the attempt to integrate the living and the non-living, but to postulate a shared "identity between living beings and self-regulating technical objects" (Simondon 2017, p. 51). Importantly, however, this should not be taken as a dismissal of the organ as a metaphor. Indeed, considering BRIM as an organ brings attention to how a building's multitude of movements and transformations are brought into different schemes of intelligibility, and how these schemes are inevitably put to work in systems that are clearly and intentionally designed around cybernetic principles of feedback and self-regulation. Yet these principles, while necessary regulatory operations, do not completely determine the functionality of the BRIM system, in the same way that a heart is not wholly determined by its capacity to pump blood, nor a nervous system by its capacity to transmit messages to the brain. In analogizing BRIM as an organ — or an ensemble of small, biting organs — the sensor network can be opened up from a potentially claustrophobic reading of privacy issues and impending climate catastrophe into a holistic exploration of the organ as a permanently *open* ensemble.

As Combes reminds us, the *openness* of a technical ensemble is what characterises the passage of concretization, not its definite forms: "concretization is not a matter of making form or structure (the determinate) more concrete … It is the indeterminate that takes on concreteness; concrescence lies in the solidarity of openness" (Combes 2013, p. 92). What results from concretization in technical systems, therefore, is a permanent metastability generated by the necessity of openness and the integration of that in-formation towards a more individualised and self-sufficient individual. The analogy of BRIM as an organ can thus be put into greater tension if the genesis of the BRIM system is viewed as an integration and intensification of the indeterminate into its functioning. In this sense, therefore, the sensate behaviour that is generated within (and indeed without) the building is itself the form of this openness, and is also what concretizes.

Kitsch (2013) argues something similar regarding Japan's high speed trains, which habitually operate far beyond capacity to the point where this over-capacity is in fact what defines its technical specificity, "whereby the entire focus of railroad operators is not on maintaining precision per se but rather on maintaining the precision of the margin of indeterminacy" (Kitsch 2013, p. 329). Kitsch defines this margin more specifically, as "the dimension in which bodies and machines, with their incommensurable qualities (technicities), intersect with the time and space of institutionalized regularities to produce a metastable techno-social environment of everyday urban life" (Kitsch 2013, p. 329). BRIM, though perhaps less precarious than an overcrowded bullet train, is similarly specified by the incommensurable qualities that are held together by the very intersection and concretization of their indeterminacy. The problematic that BRIM encounters is the incommensurability of the perception of the living and the limited problem-solving capacities of technical objects. As a solution to this problem, the sensing capacities of BRIM operationalize a dynamic schema of the indeterminacies of a building, a schema that can be analogized through the image of the organ.

The BRIM brain invokes the current political economy that increasingly privileges organic models of intelligibility (especially in the ICT sphere), which is turned towards the deepening of sensor networks' ability to mimic or approximate human sensory capacities. Accruing an appreciation of BRIM as fundamentally based in indeterminacy and openness, rather than deterministic notions of intelligibility, gives more flesh to the notion of perfection that attends these diversions in technical evolution (if we want to cultivate such an appreciation, which we may not). It also creates the possibility of asking to what ends the organic is being put and cultivated in emerging contexts, such as the micro-scale of human behaviour in an office building, and the macro-scale of climate change and privacy. It is now possible to ask, for instance: What kind of instrumental bodies do buildings become when they are made dividually intelligible and globally responsive and sensitive? What kinds of novel or recurring relations between the sensible and the sensed are cultivated when the margin of indeterminacy is the point at which sensing happens? Were we to instead start with the presumption that sensing is premised on harmony, there is no problematic through which to develop a sensitivity, as it were, to the milieux in which it operates. In the BRIM brain's case, that milieu is marked by a fundamental incommensurability. In the following case study, incommensurability is again at the heart of the sensor-milieu couple; though, unlike BRIM, this disparity does not lead to concretization into a single sense organ, but rather diverges away from the concrete and towards the abstract notion of *horticulture*.

The Arboretum

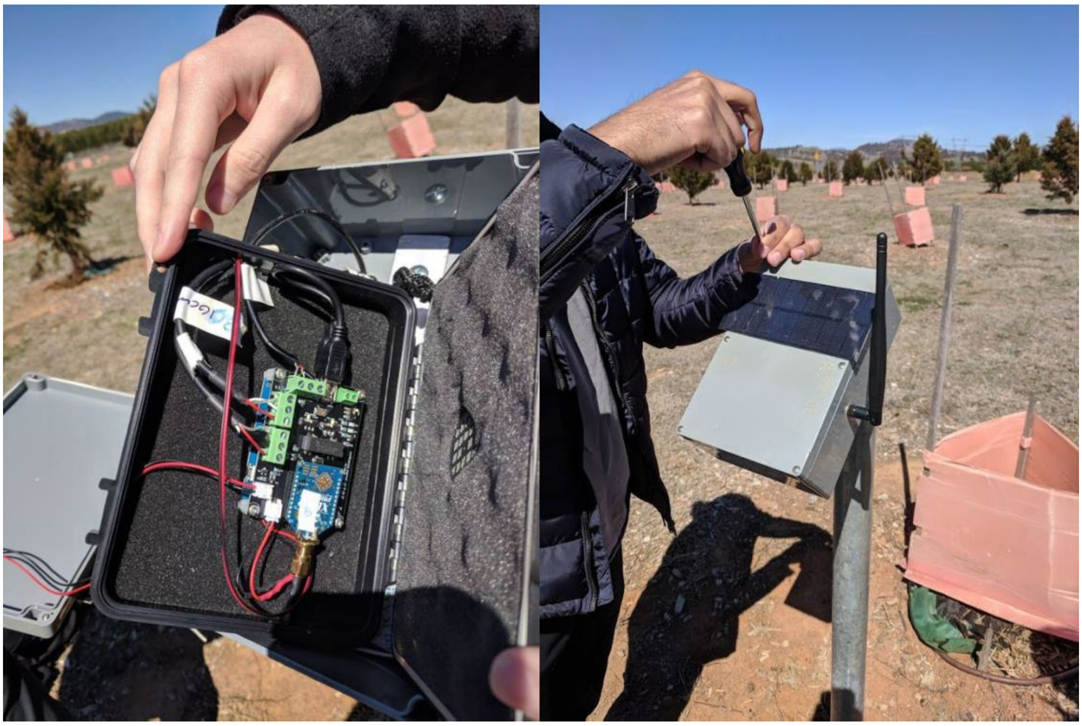
National Arboretum outlooks. Images by Author, 2020.

In 2003 the Canberra bushfires razed a cluster of rolling hills next to the Tuggeranong Parkway, a major artery in Canberra's road system. The hills had been covered in pine trees, grown in neat rows for milling and pulping. When the fire was extinguished, the trees were gone. Instead of replanting the commercial pine forest, the ACT government took back ownership of the hills and redesigned them into a tree museum. One of the largest of its kind in Australia, the Canberra Arboretum homes 94 varieties of trees. Each of these species — of which there can be as few as a dozen trunks and as many as a few hectares' worth — has their own demands on the hills.

Before the Arboretum commissioned the Smart Soil Moisture Monitoring Sensor System, a single worker was in charge of checking the soil moisture of each and every forest around the Arboretum, taking soil samples at various depths in multiple spots in each forest. It took the worker 4 months to test the soil of every forest, at which point he would begin the process again. The soil moisture sensor network was the solution to this time-consuming work, and its services exceeded the fruits of the original labour. At depths of 10cm and 55cm, sensor probes track the volumetric water content, soil temperature, and the voltage of the probe's battery. When the soil reaches an arbitrary level of wetness or dryness, it triggers the irrigation system to either water the forest or delay the watering schedule. It also triggers an alert when the battery voltage reaches a certain low point, indicating the need to replace the battery (National Arboretum 2021). Sensor data is sent from each moisture probe to a local node — a raspberry pi encased in a durable weather-proof box fitted with an antenna — which then transmits the data to the cloud and into a publicly-available website that anyone can monitor (Arboretum App 2021).

The system is currently only installed in ten forests, but Owen Bolitho, the Arboretum's Head Horticulturalist, told me in a 2020 interview that there were plans to expand the system into all 94 forests. Of the 94 forests, thirteen are made up of threatened and near-extinct tree species, two of which can no longer be found in the wild. Tourism and public biodiversity initiatives are key aspects of the National Arboretum's operations, and the soil moisture network was not distinct from these considerations. Managing and the watering schedule for the many forests has implications for the Arboretum's other functions, like event planning (predicting when a forest will be in full bloom) and safety (avoiding water-logged areas of the Arboretum after heavy rains). Perhaps most importantly, the system directly influences the way the Arboretum manages its annual water budget, which implicates the network into a larger schema of budget requirements, government-issues directives, and speculative schemas like drought-proofing. In short, the network is now far more integrated into the workings of the Arboretum ensemble than the single, dutiful worker once was, and its operations are thereby both more likely to tend towards regulation and stability, and also to become more contingent on the variations of those many external forces. Furthermore, as a system which is pre-eminently about life — keeping trees alive, noting the conditions of arboreal life, preserving the lives of maintenance workers, invigorating the lives of Canberrans — the question of how to understand that life becomes pressing.

Interested in the ways in which these pressures came to bear on the sensor nodes themselves, in 2018 I interviewed a group of students from the University of Canberra who developed the system's software, designed the digital interface, crafted the physical boxes, and installed the initial 10 nodes personally. I joined a team of three engineers on one of their installation and maintenance days, interviewing them in their lab before heading to the Arboretum to do work on the nodes. I talked to the developers as I watched and helped them install a node out in one of the forests. One of the stronger moments of the observation was the palpable feeling of joy when the system "actually worked". One of the students got especially excited when the node successfully pinged back from a nearby telecom tower:



Arboretum soil moisture sensor nodes. Images by Author, 2018.

> I tested the antenna, and I can get signal all the way at my house! … Initially I tested it with this antenna [*holds up first antenna*], and I was like sweet, got synchronisation. Then I tried it with this antenna [*holds up second antenna*], and I also got synchronisation. [*dramatic pause*] From six kilometres away! [*noises of astonishment from everyone*] … And it's all synchronised and meshed. If we had that one in the centre of Canberra and you could keep jumping across and ideally if I had more nodes [I could] link across to Queanbeyan. Which would be pretty cool.

This excitement over signal reach is probably unsurprising if you've ever met an engineer. Yet significantly, it signals the emergence of a new relationship within the system. The 'reach' signals an excess of potential, an oversaturation within the technical ensemble. The ping, the reaction of excitement, the communication between the antennae, the distance between the Arboretum and his house — all are the ways in which the system creates a temporary system of compatibility which is more capable than the compatibility can encompass.

In a strictly technical sense, the strength of the signal is not in itself an instance of concretization — as no element has been removed or converged — but rather one of saturation, signalling a resonance of the antennae and milieu co-individuating; the length of the antenna, the distance between it and the antenna in Queanbeyan, and the energy provided by the battery all undergo processes of in-formation. Concretization, in this instance, is instead occurring at a different level of the system; the convergence of multiple functions into the motherboard's semiconductors, for instance, enable the system to cross a threshold of functioning that enables the strength of the signal. All technical objects function by the jumping over limits and the crossing of thresholds, as Simondon describes:

> the play of limits, whose overcoming constitutes progress, resides in the incompatibilities that arise from the progressive saturation of the system of sub-ensembles; yet because of its very nature, this overcoming can occur only as a leap, as a modification of the internal distribution of functions, a rearrangement of their system; what was once an obstacle must become the means of realization (Simondon 2017, p. 33).

At the Arboretum, with these engineers, this rearranging leap is accompanied by joy. In noting this happy collision of affective and material individuations, it is not my intention to imply that there is a positive moral imperative behind concretization (though certainly there is a practical imperative in some instrumental cases). Though at first glance one would assume that Simondon valorizes concretization — considering he calls those objects that are more fully concretized “perfect” — it is not his claim that concretization is a goal of technical evolution, but rather that technical evolution can only be truly understood (that is, in accordance with individuation) through the process of concretization. Here, I am similarly seeking to show that the tendency for the soil moisture network to concretize, to oversaturate its capacities and leap into a new regime of functioning, is what requires explanation and understanding.

Equally, the tendency for the soil moisture network to fail and break down signals the obstacles and problems that the soil moisture network has not yet found solutions for, and which prevent its further concretization. As the engineers and I continued our journey of checking on the other sensors in the network, a series of banal fiddlings with the nodes’ interiors exposed the incomplete processes and ongoing partiality of the wider node network. We used a swiss army knife to open a box when we couldn’t find a screwdriver. One of the node’s motherboards wasn’t quite working, as a couple of its elements had been on the fritz for the past week. When the engineers opened up the box to fiddle with the board, there was much shifting of the wires, testing with external equipment, and loading up the website to determine whether data was successfully reaching the app and the cloud. Though in one sense highly autonomous in its ability to sense, collect, and act on data, the sensor node system is also extremely partial; it requires many external elements to function. It requires delicate fiddling, eyes to draw correlations between a wiring setup and the screen of a website, swiss army knives and other workarounds in the periphery, and good weather in which to perform all these tasks. The soil network’s mode of operation expresses how networked technologies are often conglomerations of unevenly concretized technical objects into ungainly ensembles.

Further, these breakdowns, punctuated by frustrated sighs, annoyed conversations, and awkward moments of puzzling, would seem to stand in stark contrast to the previous moments of excitement. However, these less joyful expressions belong to the same order of excess, indicating a saturation of potential, a resource for genesis that has not yet reached a state of compatibility. Simondon describes excess as a constitutive part of technical resolution:

> There is genesis when the coming-into-being of a system of a primitively oversaturated reality, rich in potential, greater than unity and harbouring an internal incompatibility, constitutes for this system the discovery of compatibility, a resolution through the advent or structure. This structuration is the advent of an organisation that is the basis of an equilibrium of metastability (Simondon 2017, p. 168).

In paying attention to the short, expected, even mundane instances of emotional tension at the Arboretum, we open up new ways to understand the crucial points at which its technical reality exceeds itself and can potentially generate something new.

Engagement with the excess of the soil moisture network can also redirect political engagement with technical objects towards operations that are based more clearly in their technical reality. Gabrys, for instance, argues that digital forest management practices not only generate new modes of political engagement with forests, but change how forests can be defined; that is, according to what it "is and how it operates" (Gabrys 2020, p. 7). A conversation with Owen Bolitho, the lead horticulturalist at the Arboretum, conveyed two definitions of a forest that he applies in his own work:

> What we define as a forest is a group of trees. … They're blocks, they're geometric squares or rectangles, and within the plantings there are patterns. We call those forests.
>
> [But] as the trees grow they will present themselves as forests. Because one thing that I attribute to a forest is this sense of mystery, this invitation in. You can't see from one side to the other. That to me is a forest. … If you look at the Himalayan Cedar Forest it just, there's that sense, it's like, I need to find out what's in there… It's compelling.

First here the forest has a defined sense as a set of patterns. But in the *growing* of trees, the forest arises as a different kind of relation. To be "compelled" is what signals a space as a forest. Remaining somewhat unintelligible, not knowing "what's in there", is central to the indeterminate centre that defines the forest.

For Owen, the role of the soil moisture network — or indeed any smart technology system — in creating such compelling transitory spaces was complex. On the one hand, he spoke highly of the significant time saved with the soil moisture network, and its contribution to managing the yearly water budget. Yet he admitted that the formulaic nature of the IoT system was not entirely adequate for the Arboretum as a "living collection". The Arboretum "just has so many variables". As we walked up a hill, overlooking the eastern aspect of the Arboretum, some of these different variables made themselves known.

Overlooking the Margaret Whitlam Pavilion, and a sensor node. Images by Author, 2019

The climb was steep. It was hot. We almost walked into an echidna, which had dug under one of the sensor network's watering hoses to find some shade. Owen adjusted the node's antenna because birds "love to sit on it". These sensations of the arboretum are fleeting, but Owen expressed that his job of tending to these sensations is a more continuous experience which, for him, is undeniably human. Expanding on his earlier comments, and the possibility of expanding the IoT network, he admits that:

> It's not out of the question that a drone could fly up every night from the top of this building and pick up on things, make changes in irrigation, or it could even implement fertilization into the irrigation system. [knowing smile] But it'll never be able to prune itself. It'll never be able to mulch itself. It's very much a human contact game of horticulture.

In this sense, horticulture for Owen is characterized by "the human contact game"; that is, for example, the sensations of pruning and mulching, or the adjusting of an antenna jostled by birds, or the reseating of a drip hose after an echidna has passed through. This was an important distinction for Owen, not because he disliked the IoT system or felt that it was inept. Rather, the passage of horticulture could not intersect with the passage of the technology because *they belong to different realms of intelligibility.*

Drip hose for the soil moisture network watering system, and an echidna digging for shade. Images by Author, 2019

On the one hand, the Arboretum inlaid with the IoT system is a space which can be clearly demarcated along lines and boundaries that can be maintained and verified by sense data: this forest, that telecom tower, this node, that weather pattern, this tree. But it is also a distinctly shifting assemblage of spaces that converge on and dissipate away from the sensor node network, concrescing unevenly and temporarily. The human is required for horticulture, because horticulture is not — and according to Owen, cannot be — a technical object as such. It is an ensemble, a collection of objects that require mediation, regulation and direction. At the same time, the soil moisture network makes its own temporary passage, generating both clear demarcations and muddy convergences. It passes 6 metres underground, far deeper than most other irrigation soil penetration systems, and can get to where human contact cannot (or not without ruining what it is contacting). It sits there, it regulates itself, and has a relative permanency; yet it also maintains an open relationship to replacement, maintenance, and fleeting moments of joy and rage. For Owen, horticulture itself is a temporary passage through a space that is marked by the 'human contact game'. The human contact is itself temporary, but it returns — perception is necessary to notice when a tree is dying, as much as when a tree is glittering in the early morning sun. According to Owen, and in Simondonian terms, the Internet of Things is too concrete to be able to fulfil or access the abstract function of horticulture. There are passages through the Arboretum space which can only be traversed by the operation of perception — a perception that exceeds the capacities of a sensor network, but are not incompatible with it.

Reflecting on the incompatibilities that mark the Arboretum's soil moisture network, as well as the sudden bursts of compatibility that signal its saturation, provides an opportunity to consider the ways in which IoT systems require and produce irreducible tensions as often as they resolve them into metastable states of functioning. The soil moisture sensor network highlights an incommensurability between the human practice of horticulture and the work it does underground, between antennae, lit up on screens. It brings these into relation and, importantly, does not resolve them. It does, however, resolve its own tensions: in its signal reach, its regular wake and sleep cycles, and even the retirement of the single worker who painstakingly recorded each and every forest. This mirrors a greater characteristic of IoT systems: in bringing together levels of reality that were not previously in communication, the Internet of Things illuminates this capacity and presents it as novel (or at least, valuable).

Yet, in illuminating the operations of transformation that enable such communication to happen, IoT systems also reveal that these individuative relations were already at work. In a piece on virtual reality, Andrew Murphie (2005, p. 204) argues that VR, rather than offering an 'escape' from the 'real' configurations of perception, instead reveals the fact that perceptual relations are always already undergoing reconfigurations. In reconfiguring the threshold of reconfigurement itself — what he calls "the modulation of modulation" — VR brings to light "the possibility that these relations are subject to change" (Murphie 2005, pp. 193, 205). In a similar vein, IoT systems like the Arboretum soil moisture network reveal that the 'things' of the IoT are themselves processes of disparation, tending towards continued existence or sudden breakdown, unevenly transforming itself and its milieu. The appearance of the breakdown or the signal reach, the moment of frustration or joy, are moments of intelligibility that *reveal the transformation of the intelligibility of transformation*, as well as what is made intelligible. In the next case study, we will pursue this more profound understanding of sensing, and the Internet of Things more broadly, in Mt Buffalo farm.

The Draughter

“Here’s something *really* really cool”. I’m sitting with Tom in his shed, seated next to him in front of his computer. He’s showing me the Agriscan database management system, which for now, in its beta stages, has a practical look about it. The page we’re looking at concerns one of the tags (that is, one of the animals) in the Agriscan system, and it shows a simple table with a number of columns. Each column designates a ‘rule’ that can be applied to certain set characteristics associated with the tag. Rules appear in a drop-down menu in each column, following basic ‘if/then’ logic; *if* a tag has the set characteristic of ‘female’, *then* the database will trigger the tag reader to execute a particular function. These rules come into effect when a tag goes through what is called a draughter.

A draughter (which can be adjusted for the major kinds of livestock) automatically pushes an animal in a particular direction. They go into a crush (if you’re cattle) or a metal cage (if you’re a sheep), weighs them and then sends them either left or right (or any number of directions, depending on how expensive the machine is). Usually the farmer and farmer's hands will draught the livestock manually, one by one, or make a broad decision beforehand about where the livestock will end up — onto a truck for selling, or corralled for vaccination, for instance. Usually, and in Mt Buffalo, the draughter is connected to a set of scales. In this ensemble, a farmer is able to count each member of the flock, weigh them, and, as is often the purpose of a draughting session, send animals that meet a particular weight off to one side, for selling, slaughtering, or returning to the field.

Tom developed Agriscan to intervene at this critical juncture. With the Agriscan system, which uses smart ear tags and a tag reader with a suite of software and middleware that Tom has created himself, the draughting process can be much more complex than traditional hand-draughting methods. Firstly, it is much faster; with Agriscan, up to one hundred individual tags can be scanned at once. After the data from the ear tags are read by the reader and translated by the middleware, the software analyses the data according to a predetermined protocol. This information is transmitted up into a cloud-based database, which can be managed later back in Tom's shed. Back at the draughter, the weight is recorded by the scales and transmitted to the reader, which then associates the data to the ear tag. This bundle of readings determine the lane each animal will go down. Any lamb who weighs under 40kg and is 16 weeks old, for example, will be sent to the left (for slaughter). Any lamb who weighs over 40kg and is 16 weeks old will be sent to the right (for further growing and future breeding). The animal's genetic potential is lived up to, or it is deemed a straggler who is to be cut from the flock.

Sheep ear tag and tag reader. Images by Author, 2019

In Simondonian terminology, Agriscan's multiple parts and processes can be considered an extensive technical *ensemble*. In seeking to distinguish the ways in which technical objects can be differently in-formed, Simondon determined that there are three layers of technical reality, which amount to three different modes of in-forming: element, individual, and ensemble. Technical elements, like the pressure plates in the scales, do not require an associated milieu to function, and cannot degenerate an associated milieu on their own. Technical individuals, like the tag reader, are those that simultaneously require and produce an associated milieu; by integrating its elements, the technical object is able to leap into a regime of functioning, which it constitutes and is constituted by. Lastly, technical ensembles are composed of a series of technical individuals (and their associated milieux) which require organisation in order to be kept in a common regime of functioning. Agriscan is one such series, enrolling a number of individuals and elements in its functioning, including the scales, the tags, the reader, the database, and Tom himself.

It would be tempting, from one point of view, to characterize Agriscan as a complete and coherent system coordinated entirely by Tom and the discrete operations of each of its technical individuals — including, importantly, the production of livestock as technical individuals. Yet this would be to mistake the operations at play in generating Agriscan as an ensemble, and of Tom's role in its functioning. Looking more closely at the way that Agriscan has evolved, and the operations of in-formation that characterise it, a more nuanced and inter-operational account of Agriscan can be recovered from an otherwise crude depiction of Tom as 'inventor' and Agriscan as his compliant invention. More importantly, the tendency of Agriscan towards concretization, while not fulfilling it entirely, provides an important insight into the in-formative relationship between complex sensing systems and the worlds which they claim to capture.

Firstly, the mode of Agriscan's operation as a complex and highly integrated system of sensing, communicating, and actuating must be addressed. A significant amount of work has revolved around its ability to pluralize Agriscan's operations. Specifically, the ability to sense multiple animals at once, in accordance with unpredictable and uncontrollable physical conditions, and in a way that conserves energy, has been central to its development. The key to this development has been in the combination of passive RFID tags, ultra-high frequency communication protocols, and four antennae that can achieve 'circular polarization'. The process goes something like this: the passive RFID ear tags are 'woken up' by the ultra-high frequency tag reader as they pass through the draughter gates. The passive RFID tags use what's called 'backscatter interference', which means the data on the tags is transmitted when they ‘interfere’ with the tag reader’s radio waves: “we pick up modulation on the carrier, decode that, and that’s your data”. Thanks to the ultra-high frequency, and the circular polarization of the antennae, multiple RFIDs can be woken up at once, regardless of the tag’s orientation, and with little latency. However, circular polarization is less sensitive than linear polarization and therefore requires tags to come within a closer range (50-60cm). It also demands more energy from the tag reader, which traditionally would have to be accounted for by cumbersome battery packs or individual power supply, which quickly becomes impractical out in the fields. To get around this, Tom’s tag reader is able to harvest energy from the tags due to the way that the backscatter waves return to the reader. Tom did not completely explain how exactly this is achieved; he had some hesitancy in divulging the details of his invention, and was quick to credit the help from other radio frequency engineers in developing the system. Regardless, the boon to Agriscan is significant, and central in its tendency towards concretization.

From a Simondonian reading, Agriscan’s functionality can be explained as a series of integrations that culminate in the continuous ability of the sensing, communication, and actuation functionalities into a relatively open ensemble that nonetheless tends towards greater internal coherence. For instance, the tag reader requires a level of openness to receive the backscattered interference from the tags as they pass within its range. Similarly, the digital scales rely on a margin of indeterminacy to receive the relative pressure of each animal. In a slightly different manner, Tom is able to sit down at his computer and create a new rule for the draughter at any point, based on any characteristic he can conceivably program for. Importantly, what makes these integrations possible is the fact that the original operations of transmission and power supply are *exceeded*, the effects of which cascade into the structure of the system as a whole. For instance, now that the draughter readers also perform the role of energy conservation, the network does not need to account for bulky power supply modules, which would introduce a set of demands on the system that would need to be accommodated for by other elements, which in turn would come with their own energy and space demands. Furthermore, the lack of sensitivity introduced by circular polarization is counterbalanced with the greater ability of the reader to retain energy, enabling it to read more tags at once and at greater distances than an equivalent smart tag and reader system would be able to. Thus, by integrating its functions, Agriscan achieves more than a quantitative increase in efficiency.

And yet, still, "It all comes down to efficiencies", Tom tells me. "If we wanna improve our bottom line, we've gotta move away from a mob-based management philosophy to an individual based management philosophy". What this means is that "any animal that's not performing has got to go", and tools like the draughter are instrumental in carrying this out. According to Tom, "it's a good result. I get 95% joining [successful pregnancy] for sheep and cattle... In fact my AI [artificial insemination] program is paid for by animals that didn't perform". More efficient draughting processes also contribute to the animals' wellbeing, being "less intrusive", and allowing Tom to pair ewes and lambs, or cows and calves, much more quickly. This is especially important when not all lambs or calves will drink from multiple mothers, and not all mothers will allow all lambs or calves to drink from them. Agriscan allows Tom to manage lineages, vaccinations, weights, ages, marketing schedules, feeding inputs, seasonal variances, the effects of drought, and any other number of variables. Ultimately, for Tom, "it's all about breeding and advancing the herd". To return to the question of intelligibility, the capacities of the Agriscan to make the advancement of the herd more intelligible, and therefore more able to be acted upon, becomes relatively straightforward at this point. Indeed, making these junctures intelligible at a technical as well as intellectual level is critical for Tom's running of Mt Buffalo. However, clearly this intelligibility is only one aspect, or what Simondon would call one *mode* of the co-individuation of Agriscan and the other social operations at play.

In a strictly practical sense, the convergence afforded by the Agriscan ensemble is most directly related to energy efficiency and speed of calculation, meaning that the boons of this convergence are largely quantitative. However, if considered more broadly, this convergence is not limited to the technical elements of the sensor nodes, but also enrols the livestock, Tom, genetics, money, and the drought that lasted ten years. The Agriscan sensor array allows the draughter to concretize *as a whole*, which is not to say more completely or "perfectly" in the evaluative sense, but in the sense of tending towards a more internally coherent and self-sufficient system. The demands of livestock breeding, seasonal markets, the drought, the fires, and the tinkering happening in Tom's shed are not excluded from this internal coherence, but are a resource that the ensemble will continue to draw from. Integration, though not resulting in perfect coherence, is nonetheless a key evolution in the Agriscan system — not just at the level of conquering key physical obstacles in its deployment, but also at the level of the operation of Mt Buffalo as a farm, and the multiple environments in which it operates.

Secondly, then, Tom's role as inventor can be addressed with more consideration towards the complex technical reality in which Agriscan operates. I spoke to Tom for almost 6 hours, beginning in the late morning with a cup of tea around a table, migrating to his shed, and finishing with an hour-long ride in his buggy across a section of his pastures. Across those six hours we traversed a variety of milieux, each with a character and style that could not be contained within any single object, much less my digital camera. Yet each stopping point, captured partially in our recorded conversations and my photos, provided an opportunity to consider Tom's role in how Mt Buffalo continues as its own unique collection of regimes of individuation.

Views from the buggy. Images by Author, 2019

There were many moments during the day-long interview at which Tom could have been taken as the key figure around while Mt Buffalo circulated, and through whom its intricate workings became known. And yet there were many more instances where such an image of 'the inventor' was inadequate. Before we left to find the cows, Tom only looked briefly at his phone to check their last

GPS check-in. We searched for twenty minutes, spying the horizon, relying on Tom's memory, eyesight, and instinct for the cows' whereabouts. We had to traverse a number of steep ravines that Tom delighted in carousing down, and which would have been entirely impassable without the buggy's ability to negotiate Mt Buffalo's topography. When we did find the cows, they partially fled, congregating around trees and watching us warily from the embankments of waterholes, escaping my camera and Tom's deft driving. Even from the inside of the buggy, traipsing over the pasture at speed and with Tom at the wheel, the very object of Agriscan's operations was elusive, somewhat hostile, and always just over the next hill.

Windmill and water tank IoT system. *Images by Author, 2019*

On our way into the pasture, Tom stopped us briefly to check on an IoT system he described as "in the works". He had set up an IoT-enabled water pump systemat a waterhole near his property, which would top-up the water levels in a reserve tank installed at the top of a hill half a kilometre away. One day, the windmill system will automatically pump water up to the reserve tanks when the tank reserve drops below 20% full, when significant amounts of rain are forecasted, and when water is urgently required elsewhere on the farm. Despite the relative tedium of needing to check in on the generator and the pump system regularly, Tom still spoke of the project with some joy, "[the IoT] gives me more parameters to control this stuff". These parameters, far from being neatly managed from his shed or from an app on his phone, unfold in an ungainly — but not nonsensical — manner across the paddock.

The highest point. Images by Author, 2019.

The windmill remains somewhat incoherent, functioning in spurts and then requiring maintenance again, waiting to be told when to start and stop pumping, ignorant of the rain and heat and what it might do to respond to it, or how to accommodate Tom's visions. Some of its individual elements are concretized: thegenerator can turn on and off remotely and self-manage its power supply, and the LoWaRAN radio atop the tank transmits and receives consistently and accurately. The windmill itself has different zones of concretization; its blades turn in accordance with the wind and its stands sturdily against stronger gusts, but its relation to the waterhole, the pump, and the tank is largely nascent. Indeed, what enables and pushes the windmill system into its current state of functioning is the individuation of the landscape itself. It is no mistake that the reserve tank is at the top of the highest hill within range of Tom's house; when its reserves are used, the water can passively flow down to where it is needed. Likewise, the windmill is at that particular waterhole because it is the waterhole at the closest distance and highest elevation relative to the tank, meaning it requires the least possible amount of energy from the generator to pump the water up to the tank. In short, the windmill system only operates according to these topographical and energetic relations, and its functions are an amplification of the forces that are already unfolding in the landscape.

In each of these moments, the image of Tom as an inventor gave way to a far more relational reality, in which Tom was a key *interpreter* and *organiser* of a milieu, but far from its master. It is in this spirit that Simondon describes the role of humans in technical ensembles against the common conception of a master who imparts a form upon a passive slave-like material. “Far from being the supervisor of a group of slaves”, Simondon (2017, p. 17) argues, “man[*sic*] is the permanent organizer of a society of technical objects that need him in the same way musicians in an orchestra need the conductor”. Conductors are crucial, he argues, because “it is *through* the conductor that the members of the orchestra temper or hurry one another. … He is the mutual interpreter of all of them in relation to one another” (Simondon 2017, p. 18, my emphasis). Agriscan is itself an evolving ensemble that requires Tom’s orchestrations quite regularly; banal maintenance duties, like checking the windmill generator, are moments of mutual interpretation in which the relations of the ensemble are re-oriented.

Atop one of Mt Buffalo's highest points. Image by Author, 2019

In recognising the layers of integration that constitute it, Agriscan can be viewed with more technical nuance. Agriscan introduces a set of amplified operations into Mt Buffalo's milieu which were simply impossible without it. This is not to say that its previous potentials were lesser, either quantitatively or qualitatively (though for Tom, in the context of his farming practices and livelihood, they certainly were). What Agriscan makes possible is not a greater intelligibility, but an amplification of in-formative relations that generate an ensemble in which multiple individuals (Tom, cow, draughter) are made interoperable. If our problematization of IoT sensing is based in disparity and indeterminacy, then it becomes possible to think more accurately and problematically about the process of invention at play in each and every technical system. Not insignificantly, it is also from this technical point of view that sitting down to create a new draught can be appreciated as "really, really fun". Being attuned to such affective forces, which we will address in the next and final Claim, is equally important to understanding the way in which technical systems are integrated into other regimes of individuation — namely, those collective individuations that in-form and are in-formed by the Internet of Things.

5
Actuation as Transduction

In this final theoretical chapter, I would like to return to the critique with which I opened this thesis: the critique of the representational mode of thinking, the presumption of the pre-existing individual, and the way in which these modes of thought have created a scenario that renders technical ensembles largely unthinkable. Representationalism, as discussed, is a mode of thinking about the real that positions the world as fundamentally given, which often if not always results in the idea that individuals, environments, and events are essential and ultimately fixed. As I have indicated, this representationalism has technical and practical utility and it functions, at a common sense level, to explain the Internet of Things' participation in human affairs and the world at large. However, a representational account is poorly equipped to account for the ways in which the Internet of Things actively participates in processes of individuation and the becoming of the world, a becoming that is more than a mere change in things, which for their part are always already given in their identity. The habit of thinking representationally leads us down a particular path of problematizing the Internet of Things which, as I have shown, does generate modes of engaging with the IoT and technology as a whole, though towards particular ends. I have argued that communication and sensing are involved in operations that exceed representation and, as such, are better understood as modes of modulation and concretization. Yet, claims to engage in communication and sensing do not, in and of themselves, distinguish the Internet of Things from generic sensor network systems. Rather, it is the *actuating* capacity of the IoT that is at the heart of its distinct claims upon the real. In advancing the sense of what is at stake in a processual approach to the technical operations of IoT systems, it is to this question of actuation that I turn. The focus of this chapter, then, is the claim that IoT systems transform the possible into the real.

Actuation, perhaps more than communication and sensing, produces a strong sense of the transformation and change within a system. According to the common sense, representationalist approach, the Internet of Things is able to apprehend real individuals, environments and operations in such a way as to determine their potential to act and transform over time, and to harness that potential towards an arbitrary goal — be it efficiency, political liberation, profit, climate change action, or any other end. Actuation, in putting the environment and its machinations into motion, animates all the potential claims that can be made by an Internet of Things system. To return to the formula with which I began the thesis: the claim to record life in such a way that can be acted upon is akin to the claim to articulate that which is real, but not yet present. Actuation is dependent upon what has been sensed, which is to say on what the IoT has determined to be a real aspect of its environment. As such, actuation is able to make a strong claim on the possibilities inherent to a given environment. Actuation is thus framed within the ontology of the possible/real distinction; consequently, actuation, and the IoT as a system, can persuasively lay claim to the potential futures available in a given environment. More importantly, actuation can effectively bring one or some of those futures into being through a series of events, and subsequently make those futures appear as natural or inevitable. Thus, in an Internet of Things system, acting on life becomes indistinguishable from the process of deciding how to act. Action and transformation is already determined by the apprehension of sense towards communication, allowing the claim of an IoT system to become universal, invisible and immanently *valuable*.

There is a wealth of opportunity to examine more closely the labour relations being produced by the Internet of Things on a truly global scale; as I signalled in the second chapter, the IoT is overripe for such a reading. Yet, analysis geared towards value as a commodity can too easily gloss over the technical processes which produce it. Similarly, approaching value as a social fact waiting to be revealed cannot adequately speak to its production. Thus, this chapter will instead provide a way of thinking about the concatenation of acting and deciding how to act, and its transformation into value, as a problem of the relation between the possible and the real. To do this, I will first challenge the possible/real distinction by turning to Simondon's concept of the preindividual, in order to free actuation from the representationalist evaluation of technical systems according to their fidelity to a given reality. I then deploy Simondon's concept of transduction to open actuation to a socio-technical becoming that connects disparate fields and produces unforeseen transformations.

5.1 Value

> It's about making things work. It's about making things do stuff. And the IoT does stuff! (interview with Tom Gunthorpe, after I asked him what makes the IoT fun)

Etymologically, "actuation" has roots in spiritual texts reaching back to the 1600s, often signifying the awakening of the human spirit by a holy force (OED 2021a). By the 1700s the term found its way into medical texts, signifying the action that allows a body to be set into motion (OED 2021a). As early as the 1920s, actuation's association with movement and awakening was borrowed by mechanologists to signify processes where an operation or process is "activated" in some way. 'Actuator' was thus the name given to the mechanical elements within a technical ensemble that performs the activation, and 'actuation' describes the physical transformation. More precisely, actuators are "elements that can act on themselves, sensors, or the environment, and could be static (e.g. water sprinkler) or mobile (robots)", and in IoT systems, actuators are specifically a combination of digital and physical elements (Stojmenovic 2014, pp. 122-123). While the spiritualist overtones of early uses of the word would jar with contemporary technical sensibilities, there is clearly an element of them in the way that practitioners like Tom talk about the Internet of Things: the IoT "makes things work, it *does* stuff"; it *awakens* "things".

Pertaining broadly to physical transformation, actuation is a necessarily vague and widely encompassing technical concept. It includes "any mechanism by which an agent acts upon an environment. The agent can be either an artificial agent or any other autonomous being" (ITU 2006, p. 11). As discussed in Chapter 4, technical literature positions both sensors and actuators as residing in the same classificatory space as different kinds of transducers. What separates them has little to do with physics, but rather "the intent of the application" (NRC 1995, p. 11) and, to some extent, their energy efficiency (Sinclair 2001, p. xi). While recognizing this technical similarity, I will nonetheless be maintaining the distinction of actuation from sensing in order to investigate its *relational* significance within an IoT ensemble. Similar to communication and sensing apparati, actuation is characterized by a suite of co-determining operations and needs. Actuators can be plurifunctional, but the measurand, along with the internal communication array, determines what kind of actuation is needed (Janocha 2004, p. 1). In biochemical engineering, for example, it is usually the opening or closing of a pneumatic valve; in automotive systems it is characteristically the rotation of a motor or force applied to a container. There is an arbitrary "target value" (e.g. close the valve halfway), a possible disturbance (the valves are too hot), the actuation itself (the valve is set into motion) and the output (the valve does not close) (Janocha 2004, p. 2). In IoT systems, by far the most common energy input is an electrical pulse, which is then transformed into a mechanical movement (Naito 2015, p. 2599). The pulse, followed by the movement, can happen in a tiny fraction of time, but the actuation sequence requires a number of steps:

> [An IoT system] uses a device (such as a sensor or meter) to capture an event (such as temperature, inventory level, etc.), which is relayed through a network (wireless, wired or hybrid) to an application (software program) that translates the captured event into meaningful information, which can trigger

an actuation (Stojmenovic 2014, pp. 122-123).

Thus, many different movements can be operationalized by IoT actuation, but all can be classified as *events of transformation* that are *triggered* by previous operations.

“Events” — and their triggers, which are themselves events — have a central significance in actuation, especially in the way that actuative processes have developed in IoT networks and digital systems more broadly. Though IoT actuation mechanisms pass through one physical relay or another, they are usually, if not always, digitally mediated, which means that they must be signified as information. A brief explanation of the mathematical understanding of the event is useful at this point, to grasp the manner in which actuation is rendered a quantitative operation, which is directly related to that which is both *possible* and real in an IoT system. Mathematically speaking, an event is a single possible outcome of a "sample set" of outcomes (Papazoglou 1998). For example: when we flip a coin, the sample set is {heads} or {tails}. {heads} constitutes an event, as does {tails}. Even as the sample set gets bigger and more complex (drawing from a deck of cards, rolling ten 6-sided dice, and so on) the event remains singular. Singularity is similarly applied to actuation events, which are defined as “an action that occurs at an instant or over an interval of time” (ISO19136 2020). Similarly, in order to recognize, relay, and translate an event appropriately, the IoT system must have in place a “sample set” of possible events and triggers. Actuating is thus a process that, in instigating an “actual” state of affairs over a period of time, also invokes a set of “possible” events.

In discourses on the political potentials of actuation, the focus is, perhaps not surprisingly, on how an IoT system might selectively realize a possible world. In the realm of smart city and other public infrastructure, actuation has been figured as a privileged site of public participation, with IoT systems themselves being regularly referred to as “active participants in business, information and social processes” (Vermesan & Fries 2011, p. 10). Actuation is seen as enabling a shift from a paradigm of “citizen sensing” to “citizen actuation”, bringing along with it the promise of realizing the possibility of a truly “citizen-centric” city (Crowley, Curry & Breslin 2013). Equally, however, there are concerns that IoT actuation makes possible a world in which human modes of deliberation, governance and critique are effectively, if not entirely, bypassed (Asaro 2012; Jones 2017; Zalnieriute, Moses, & Williams 2019). Whether it is the effective disappearance of humans from technical processes or their over-presence (as in critiques of bias-laden algorithms (Noble 2018)) the implication is that technical operations are mere tools for realizing a possible, pre-given world, according to the whims of what or whomever controls them.

At this point, the lack of specificity to the operation of actuation becomes something of a problem. If actuation is generalized to “movement” or “event” based in the realization of a set of possibilities, then our problematization of it will be similarly aimed at its generality, rather than its specific technical reality. Of course, it would not be possible here to exhaustively cover the multitude of ways in which actuation can occur. I will therefore discuss a specific use case of IoT actuation by drawing on, and modifying to my own ends, an example laid out by Bassi et al (2013) in *Enabling Things to Talk*. Their example of IoT actuation illustrates that while events may need to be quantified as sets of possibilities in order to produce an effect in an IoT system, the qualitative mechanisms at play in actuation are equally necessary to its functioning. Technical function, in this instance, is directly related to *value*.

The example begins with a truck driver delivering orchids to a supermarket. Bassi et al (2013) describe a truck fitted with an extensive sensor network, connected to an internal air conditioning system and a telecommunications channel, among other things, to monitor the orchids it transports. Orchids are delicate flowers and require a specific climate to retain their shape and health, especially on long journeys from their carefully controlled greenhouse into the relative climactic chaos of a point of sale. A truck driver is transporting the orchids between a rural farm town and a major city 12 hours away. For the orchids to survive the trip, they need to be kept in a regulated environment. During the long trip, if the shipping container carrying the orchids exceeds certain thresholds (too hot, too cold, too wet and so on), a climate conditioning unit in the container is adjusted, and the driver is notified by SMS that an adverse climatic event has occurred and is being managed by the conditioning unit. The driver will be alerted again if the conditioning unit cannot address and regulate the climate back to within its designated thresholds within a certain timeframe. Once the driver arrives at the supermarket, the truck's IoT system connects to the supermarket's IoT system and communicates the log of climate information recorded during the trip. We can note that this could also be happening during the trip, but we can assume that for proprietary reasons this information is not released until delivery. The supermarket's IoT system, using pre-recorded data from the Internet as well as its own stores of data, assesses the climate data to determine a number of things: whether the orchids will survive for the next few days in order to be sold; what temperature the supermarket's internal air conditioning unit needs to be set at to accommodate for the specific number of orchids and their condition, and so on. The IoT system, most likely in conjunction with the approval of the supermarket's manager, though this is not necessary, can then determine whether the orchids should be bought and how many of them can be accommodated within the store, for how long, and at what price. When the orchids are eventually placed on store shelves, they are given individual digital price tags and sensors, which change the price according to the individual flower's health (their soil temperature, moisture and nutrition content, for example). Any arbitrary measure imposed by the supermarket's IoT system will also be attributed at this point: perhaps, for example, the orchids will be more expensive on Mother's Day or when the weather is warm and sunny outside or will become cheaper if no flower sales are recorded for two days. The possibilities, it seems, are endless.

In the relatively banal example of the orchid driver, actuation covers an enormous spectrum of possible actions: flipping a switch, pushing a button, turning a motor, opening or closing a gate, compressing air, turning a screw, pulling a belt, clamping an object, polarizing a magnetic field, heating an element. Actuation happens, too, at a number of points — each time the sensor network is instigated to take a reading; when the driver is alerted by SMS; when the air conditioning unit's parameters are changed; when the climatic logs are delivered to the supermarket; when the orchid prices are changed; when the supermarket's conditioning units are adjusted, and so on. And this saturation of the system with actuation points produces value in multiple ways and for multiple entities, all in relation to these moments of actuation. The driver does not have to stop and check the orchids regularly, and does not have to worry about learning the complexities of orchid care to make the delivery. The supermarket owner does not have to worry about being stuck with dead or soon to be dead flowers, or about how to care for the orchids according to the stresses acquired during the journey. Customers gain value from the differential pricing of the orchids, and a more meta value emerges from the ability to choose orchids depending on their prices and, implicitly, their quality. There are also enormous opportunities for value to arrive in the form of advertising. For example, if the orchid section of the supermarket is colder than the rest of the store, customers in that section will be shown ads for hot beverages, or be offered a discount for orchid-specific soil.

There is something rather reductive, even humdrum, about the kinds of value such technical operations bring into being. Yet there is also a risk of accepting this quantitative account of value as the realisation of pre-given potential as the only account of what takes place through such operations, which are, ultimately, far more processual in nature. Creating value from its processes of interconnection and interoperability has long been a part of the Internet of Things' defining features, beginning with Kevin Ashton's original hope to develop the IoT for vast machine-operated and Internet-connected supply chains (Minerva, Biru & Rotondi 2015, p. 18). Specifically, what is interconnected and made interoperable are the digital and physical realms. “At its core”, Wortmann and Flüchter argue, “the Internet of Things is characterized by the combination of physical and digital components to [...] digitalize functions and key capabilities of industrial-age products [...] to generate incremental value” (Wortmann & Flüchter 2015, p. 222). A lightbulb, for instance, can generate its “thing-based physical functions” of supplying light, but can also generate an “IT-based digital service” of late-night security in public spaces (Wortmann & Flüchter 2015, p. 222). Focusing on “services”, some have connected the value of IoT systems to a wider “behaviour economy”, a phase of economic development “in which people no longer engage with brands just by purchasing things, but they look for engagement with services that allow them to behave, to leave a mark, to participate with others” (Manu 2015, p. 9). Value in this economy is not just “value for money”, but the fulfillment of a variety of personal needs, which the Internet of Things achieves through its ability to capture and deliver “value moments” (Manu 2015, pp. 9, 18). In these accounts, “value” signifies what results from the interconnection and interoperability of the digital and the physical. Turning to a critique based on value as a product of IoT systems would be correct in the sense that IoT systems play a large role in the evolving service economy (Haller, Karnouskos, & Schroth 2008; Ehret & Wirtz 2017; Balaji & Roy 2017). However, to focus on value purely as a product would downplay the technical processes that are implicated in its generation. It would, furthermore, miss the specific ways in which the *potential* of interconnection and interoperability are important to IoT-derived value; at least as important, in fact, as any actualizations.

The problem here is not so much value per se, though its realisation in contemporary capitalism frequently involves grossly reductivist and exploitative modes of operation. As I have suggested, to abandon value would be to deny a crucial element of the operations and effects of IoT systems. If, for many, “value has long been dismissed as a concept so thoroughly compromised, so soaked in normative strictures and stained by complicity with capitalist power, as to be unredeemable”, Brian Massumi for one insists that value is too important to be left to the “purveyors of normativity and apologists of economic oppression” (Massumi 2018, p. 3). In *99 Theses on the Revaluation of Value: A Postcapitalist Manifesto*, Massumi declares that “it is time to take back value” and that the first step in such a revaluation is to “uncouple value from quantification” (Massumi 2018, p. 4). Certainly, to the extent that the Internet of Things is conceived as a means of realising value conceived in purely economic terms, its operations are invariably reduced to a quantitative register.

If seen less as a realization of possibility and more as a process of actualisation, the value that emerges in actuation may be grasped in its multiplicity and heterogeneity, emerging at a number of distinct and somewhat indeterminate points and across diverse levels. A representational account of actuation-as-realization rests on the presumption that actuation acts on things that pre-exist the process of realization. It assumes too that the thresholds that trigger actuation are essentially quantitative in character — a quantitative increase in temperature, for instance, within a given quantity of time. In contrast, to focus on the constitutive processuality of the kinds of technical operations outlined in the above example enables us to see the “irreducibly qualitative” character of value, before and beyond its capture by the "purveyors of normativity and apologists of economic oppression" (Massumi 2018, p. 3). Beyond capital-based surplus-value (Massumi 2018, p. 4), process ontology itself produces a surplus value, though it is "purely qualitative and concerns the intensity of lived potentials" (Massumi 2018, p. 16). Capitalist and process surplus-value are connected, of course, but not equivalent; "the former is the systemic capture of the latter" (Massumi 2018, p. 16).

The question of value is a significant one that requires careful attention. As often as the actuating capacities of IoT systems are spoken of (the automatic opening of a cow gate or the watering of a field), equally often is the presentation of the data produced by an IoT system positioned as the system's greatest "value-add" (Chen et al 2015). However, as I discussed at the beginning of the thesis, the actuating capacity of IoT systems is often what defines it from other sensor network systems, which for their part would merely generate data (Granell et al 2020, p. 393). To recall, the basis of IoT communication in heterogeneous realms expresses itself as modulation, which is to say as a constant and variable modulation of material potentials, which makes them available to being in-formed. The tendency of IoT sensing to make different layers of reality interoperable is also expressed as concretization; namely, as the ability of a technical object to integrate its *preindividual* reality with its milieu. Actuation follows as the actualization of these processes, yet remains involved with their potentials and preindividual realities. My contention is that IoT actuation *actualizes* these realities — if only partially — which is then commonly taken as the generation of value. The Simondonian implications of this may already be apparent. However, for the moment, my concern is to investigate the ways in which value and technical processes of actuation are rooted in this sense of value as connected to potential.

Ultimately, the Internet of Things is a commodity, and thereby imbricated within the capitalist system of value. Denying this does not deepen our understanding of actuation, but rather limits it by refusing to consider value as an actual mode of the Internet of Things' operations. I do, however, wish to deepen the discussion around value and the IoT by exploring the technical basis of actuation, and specifically its relation to potential. As shown briefly above, actuation produces value, and that value is produced as a potentiality as well as an actuality. Therefore, the operation of actuation is itself a process of bringing into being a claim on potential via its actualization.

This aspect of actuation should be further explored in order to sufficiently respond to critiques of the Internet of Things as an ultimately reductive capitalist assemblage and to adequately address the question of value in an IoT system. To do this without the baggage of representationalism, we require a different concept for understanding the individuation of potentiality within a technical ensemble. Specifically, the formula of the possible/real that ascribes value to the determination and actualization of the possible needs to be rethought. The technical reality of actuation also needs to be further investigated, to understand how the relations of potentiality are a part of its individuation.

5.2 Preindividual

My concern in this section is to question the usefulness of the possible/real distinction in analysing the technical reality of actuation. I have been arguing that actuation tends to be seen as an operation of realizing a possibility or set of possibilities, and that value is understood to be generated in this process of realization. For one, as we have already discussed, the possible/real already misses the ways in which *potentiality*, as distinct from *possibility*, is already recouped through capitalist value-generation. Furthermore, to consider actuation as a process of bringing into being that which already exists as a possibility would presume that actuation is led by a pre-existing *principle* that enables it to materially realize an ideal event, transformation, or mode of sociality. Again we must question this form of substantialism and challenge the mental schemas that would subjugate both technology and collective life to a predetermined relation of either mastery or alienation.

The possible/real distinction implies that a technical system progresses by a series of events in which potential states are fully realized. This proposition lacks an explanation for the element or resource by which a technical system can both maintain itself and transform over time; as Simondon puts it, “stable equilibrium, in which all potential would be actualized, would correspond to the death of any possibility of further transformation“ (Simondon 2017, p. 177). In any given IoT system, a number of transformations in its functioning are undergone — the transformation of electrical energy into a mechanical force, as in actuation, or of a physical energy into electrical signal, as in sensing. As such, a mode of analysis is required that can account for ongoing transformation, and which can explain the source of those transformations without turning to reductive accounts of ideal forms. With this in mind, this section will indicate that actuation is involved in something quite other than the realization of a pre-given possible, by giving an account of the mechanisms by which actuation invokes potentiality in its operations, and the resources by which actuation continues to transform and to provoke new transformations.

Firstly, the question of the potential of IoT systems needs to be addressed in terms of its technical specificity. What relation does potential have to the operation of actuation as an event of transformation? We can answer this question with concepts we have already established in the earlier chapters on communication and sensing. Each technical system lies in a state of tension, which resolves itself through disparation — that is, through the emergence of information as the signification of this tension resolving itself from metastability into stability (Simondon 2009a, pp. 9-10). The way in which technical systems resolve tensions and produce information is guided partially by humans and also by their specific material tendencies and constraints, in a process called concretization (Simondon 2009). It is important to consider these tensions and tendencies as fully real, and not just as conceptual metaphors, as Simondon stresses:

> Tensions and tendencies can be conceived as really existing in a system: the potential is one of the forms of the real, as completely as the actual. The potentials of a system constitute its power of coming-into-being without

> degradation; they are not the simple virtuality of future states, but a reality that pushes them into being (Simondon 2017, pp. 168-169).

Potential, then, is a *fully real* characteristic of a system *in tension*. It is what allows a system to literally come into being. But what, exactly, constitutes this coming into being? How would potential/tension resolve itself through the operation of actuation? On the point of coming into being, Simondon is very clear:

> Coming-into-being is not the actualization of a virtuality or the result of a conflict between actual realities, but the operation of a system with potentials in its reality: coming-into-being is a series of spurts of structurations of a system, or of successive individuations of a system (Simondon 2017, pp. 168-169).

What Simondon provides here is a precise way to consider the coming-into-being of a technical system as predicated on potentiality, as opposed to the dialectical or substantialist approaches that would paint this potentiality as a possibility waiting to be realized. The orchid truck, for instance, comes into being as a system by merit of the potentiality present in its reality (the vitality of the flower; the vigilance of the truck driver; the fidelity of the internal communication system), which come into relation in such a way that enables the system to successively individuate (to maintain the truck at a certain temperature; to alert the driver when something fails; to transmit its position to the wider supply chain network). Actuation is but one of the means by which a system's tensions are put into relation in such a way that leads to further individuation. What technically differentiates actuation from other operations is its specific, material, and fully real potentialities — which is to say its tensions and tendencies. Actuation transforms the relations of an IoT system in such a way that structures it for further individuation.

It is still unclear, however, what the source of this potential is. Could we not still consider potential in terms of the material possibilities of the elements, which are only unlocked in particular combinations, and might thus be understood as a substance that requires freeing? This assumption of a matter that is passive until informed by its principle of individuation, however, involves a fundamental error; namely, and as Simondon insists, the error of presupposing the individual that one seeks to explain. In direct contrast to the hylomorphic schema's presumption of a world filled with pre-made entities, Simondon famously posits a preindividual field; what Voss (2018, p. 100) describes as "the dimension of being which provides the material and energetic conditions for processes of individuation". Simondon's approach, we should recall, is to "know the individual through the individuation, rather than knowing individuation through the individual" (Thacker 2009, p. 89). There are by now a number of interpretations of Simondon's concept of the preindividual, with two of the more well-known interpretations focusing on its naturalism (see Virno 2009) and its relationality (see Combes 2013). Drawing out the political implications of such approaches, Toscano (2007) emphasises that the Deleuzian reading of the idea of pre-individuation moves us beyond the common sense notion of *diversity* (diverse things, diverse functions and so on) toward the *differential* and *disparate*. As Toscano (2007, p. 3) puts it:

> Deleuze casts the preindividual as a transcendental field populated by disparate singularities and series, rather than as reserve of creativity that could express itself in a given political occasion.

Leaving aside for the moment the question of the political significance of such an interpretation, what interests me in the Deleuzian reading of Simondon is the notion that the preindividual is not regarded as a common source of potential, but as one *mode of being* in which disparate series are brought into relation, in such a way that their disparity is not resolved or exhausted. It is in this manner that the transformative capacities of the preindividual are retained. As Manning (2010, p. 117) suggests, the preindividual as it figures in Simondon's work "is aligned with what Gilles Deleuze calls 'a life' — the force of living beyond life itself." As I will explain, what this means is that actuation is never an exhaustive, closed or determined function, insofar as it expresses a *partial* actualization of a preindividual reality.

It is important at this point to consider actuators, and the concept of actuation, more closely. Actuators engage in the process of material transformation, as sensors do, converting electrical energy into physical energy. Their purpose and function is to traverse energetic magnitudes. Actuation designates the process by which these magnitudes are crossed, resolving into a recognisable event. When the orchid truck mists its bouquets after an arbitrary humidity threshold is reached, there is a conversion of electrical energy (a message to a water pressure valve) into physical energy (the release of the valve to allow water through a mister). This operation is accompanied by an excess of individuations; the orchid truck, for instance, generates an excess of sensory individuations that its network must continually try to integrate into its functioning. Actuation is the crystallization of this potentiality (the fully real tensions of a system) into a new configuration. When the orchid truck actuates the misters, the entire ensemble crystallizes into a different configuration, even if that configuration is not significantly different in terms of the system's functional parameters and thresholds. In Deleuze's terms, actuation *produces* the diversity of a given state or phenomenon, but it is *conditioned* by the difference and disparity of the preindividual.

Importantly, actuation also generates in its resolution the time in which it occurs. Time is generated both semiotically (i.e. in time stamps and relative intervals) and ontologically; as Simondon (1964, quoted in Barthélémy 2012, p. 222) puts it, time itself "develops out of the preindividual just like the other dimensions according to which the process of individuation takes place". The concept of the preindividual thus provides a new way of thinking about 'events' that elides the possible/real distinction even further. In the previous section, we discussed the fact that events are a cornerstone of thinking about actuation as based in a logic of the possible/real. As units of time that express a 0/1 state, the event captures the operation of actuation according to a pre-given set of terms. If we instead consider time as one of the products of actuation, rather than the structure in which it occurs, then the coming-into-being of the IoT system can be investigated on the terms of its potentiality rather than its possibilities. This means, in essence, that actuation can be understood from the point of view of the transformation of its preindividual field into its material individuations.

We think of actuation as representing a possible reality, yet clearly such realities can ever only be partial; actuation expresses a partial actualization of a preindividual reality. Whereas the possible/real distinction can be said to be ultimately concerned with determining the real as the eventuation of a pre-existing possibility, the preindividual is concerned with understanding how the present is constituted by a multiplicity of virtual forces, which do not equally actualize. Indeed, if the preindividual was entirely actualized, there would be no possibility of novelty. In the case of an IoT system, there would be no pressing virtuality or realm of potential from which to transform one kind of energy into another, or indeed to generate value. It could be argued that partiality is itself a source of value generation in IoT systems, though not according to the common sense idea that piecemeal technical accomplishments are valuable as partial realisations of the sum total of possible technical functions.

In this section we have considered the conditions under which actuation partially resolves the real tensions of a system. I have argued that this partiality is critical for understanding the fact that IoT systems are not merely engaged in sensing or representing the data of the world with an eye to acting upon it, but are actively involved in its transformation. What now needs to be attended to is the proceeds of this transformation; that is, the novelty that returns to the IoT system in the process of actuation. The following section will discuss actuation as an operation of disparation that is nonetheless capable of inventing new structures and modes of being.

5.3 Transduction

To recall: actuators are transducers. Transducers are responsible for the activity of energy transformation. Typically, actuators transform electrical energy into mechanical energy. By merit of this transformation, two distinct levels of reality an electrical pulse, and a material mechanism — are brought into communication and generate an effect that exceeds their original sets of potentials. Actuation thus expresses *interoperability* in its very operation and structure. Previous chapters have explored the means by which interoperability occurs in IoT systems; in fact, interoperability has been at the heart of these operations. In communication, heterogeneous individuals become interoperable through disparity. In sensing, the individual and milieux integrate in order to progress. Actuation culminates these operations of interoperability, and is itself an inter-operation of electrical and material reality. However, this process is not straightforwardly linear. On what basis, then, does this interoperability occur?

Though each chapter has considered a different operation in order to rethink the basis of its functioning, at this point we can consider communication, sensing, and actuation as fundamentally co-constituted operations. In Chapters 3 and 4, communication and sensing were reconsidered as fundamentally metastable operations that are inseparable from their milieu, allowing them to concretize and persist via successive modulations. Under these reformulations, technical objects are not, and cannot be, *whole* or *unified* objects to be investigated as such (though they can achieve 'unity' as a temporary side effect of their functioning). Instead, a given IoT system is always only partial, incomplete, progressing by leaps from one state into another, and producing individualized effects along the way. By reconceptualizing these technical operations, we have also generated a different way of *thinking* about the Internet of Things — namely, from "the" Internet of Things as a problem, to IoT systems as partial expressions of different problematics. Communication expresses the problematic of heterogeneity, to which modulation arises as a provisional solution. Sensing expresses the problematic of integration, to which concretization arises as a provisional solution. As we have discussed so far, actuation expresses the problematic of potentiality, a problematic with particularly critical intersections between matter, time and participation. Any provisional solution that arises from actuation must therefore speak to each of these domains. In this final theoretical chapter, I contend that the concept capable of doing such work, and of propelling the Internet of Things into a framework that is adequate to its technical reality, is *transduction*.

Transduction is, at its simplest, an informational activity: it is the activity by which the informational characteristics of a system propagate through transformation. Modulation and concretization are also informational activities, though they concern the consistent mediation and integration of in-formational relations, respectively. Unlike modulation and concretization, transduction *changes* informational properties and structures in order to generate something new. Simondon describes it in this way:

> an activity gradually sets itself in motion, propagating within a given area, through a structuration of the different zones of the area. Each region of constituted structures serves as a principle of constitution for the next region, such that a modification is thereby gradually extended at the same time as the structuring operation (Simondon 1992, p. 313).

In other words, transduction is the propagation, little by little, of a constituted ensemble towards an ensemble still in the process of being constituted. Animals and other living beings are "essentially transducers", according to Simondon; in its most basic state, the living being "stores chemical energies and then actualizes them during the course of different vital operations" (Simondon 2017, p. 155). Transduction is not limited to the living, however; Simondon is quite clear in insisting that machines are equally capable of entering into transductive relations as long as they have a "certain margin of localized indeterminacy in their functioning" (Simondon 2017, p. 155). In a later publication, he declares that machines and technical processes are in fact:

> privileged sites of transduction, which operate by reconfiguring heterogeneous physical, vital and social milieus, themselves composed of different informational structures and potentials, into relations of "recurrent causality" that are generative of new ontological realities (Simondon 1980, p. 66).

It is precisely this point, that technical processes reconfigure heterogeneous milieux to create a new reality, that summarizes how the operations of communication, sensing, and actuation contribute to the transductive processes of an Internet of Things system. Before transduction can happen "there must be some disparity, discontinuity or mismatch within a domain; two different forms or potentials whose disparity can be modulated" (Mackenzie 2002, p. 25). The very basis of their disparation "is integrated into the system of resolution and becomes the condition of signification" (Simondon 2009b, p. 12). Therefore, disparity, the terms on which heterogeneous levels of reality actively differentiate from each other, is the precise condition on which these realities can become integrated. Incompatibility enables interoperability.

Along with "topological" disparities, temporal differences are also "restructured across some interface" by transduction (Mackenzie 2002, p. 25). Time is not the framework within which transduction unfolds; instead, time itself is "the solution and dimension of the discovered systematic: time comes from the preindividual just like the other dimensions that determine individuation" (Simondon 1992, p. 315). Accounts of actuation that stress its ability to represent a change in an environment, or to bring about a possible reality, can thus be identified as inadequate to its temporal reality. Grosz (2012) describes transduction as an operation that enables the past and present articulations of the preindividual to move into "an unknown future" (p. 43). Yet, I believe that Massumi (2012) captures it better when he argues that transduction is the process of the future acting *on* the present (p. 25). Transduction brings future relations into the present, which potentialize preindividual forces and kick them into gear. By this logic, technical objects do not have a "historical cause", but an "absolute origin", a point at which a future potentiality came into effect and was able to resolve itself into a self-sustaining regime of individuation (Massumi 2012, pp. 25-26). Massumi describes the coming together of a cognitive schema and concretization as a "transductive series", as "a forwarding of futurity down the processual line of absolute originations relaying each other, in operatively analogous takings-form" (Massumi 2012, p. 34). The power of invention does not come from the mind of an inventor (an abstract idea imposed upon passive matter), but *from the future*. In this way, the proclamatory discourses of the Internet of Things are correct; it really does bring the future into being. The processes that enable this to occur, however, are starkly different from the conventional accounts of its functioning, which assume the hylomorphic imposition of an abstract idea upon passive matter, the capture of a pre-given state in an intelligible form, or the realization of a latent possibility in an actual event.

I have thus far stressed the technical reality of communication, sensing, and actuation, which has often involved the material and practical transformations that enable an IoT system's functions to eventuate, and I have challenged the representational interpretation of them. Ultimately, this challenge requires *thinking itself* to come into question, to be freed from representational biases, and to be reconsidered as a constitutive aspect of technical reality itself. The notion of transduction provides a means to do so. As Lindberg argues, transduction is "an imaginative way of solving practical problems by transferring old elements into new individuals and thereby changing the elements themselves" (Lindberg 2019, p. 307). Adrian Mackenzie puts it this way: "transduction occurs in and as thought. Thinking can be understood as an individuation of a thinking subject; not just something that someone who thinks does" (Mackenzie 2002, p. 18). It is in thinking that transduction produces something that a representationalist account of actuation cannot. To put it simply, thinking the Internet of Things transductively can produce opportunities to *transform* the human-technical relation.

One significant, though far from exhaustive, way to do this is to reconsider the methods by which human and technical life participate in each other. According to the hylomorphic schema and the representationalist framework, participation happens on the basis of a similarity between two or more constituted entities. We saw this theme repeated in communication as connectivity, sensing as intelligibility, and actuation as value; all these formulations of the Internet of Things' operations presume to some degree that technical activity requires firstly a shared recognition of something that already exists. With each of our reformulations, however, what is commonly presumed to pre-exist technical activity was shown to be generated by it. To understand communication as based in disparation means that connectivity is generated by continuous modulation. To understand sensing as an operation in and of the milieu means that intelligibility is a by-product of ongoing processes of concretization. And to understand actuation as arising from preindividual tension means that value is produced by transductive operations. Again, this is not to argue that connectivity, intelligibility and value are lesser or unimportant elements of technical ensembles or of human life. What I have been attempting to show throughout this thesis is that to *begin* with these categories is to deny the lively and in- formative operations of the technical object. Specifically, it denies the ontologically participatory nature of technical activity, which also denies a consideration of the ways in which the human and the technical might in-form each other, and in-form each other in a way that is not immediately or inevitably controlling.

We began this chapter with actuation as a problem usually concerned with the generation of value, and with the tendency to conceive of actuation as the eventuation of a possible reality. In such a deterministic scenario, actuation can only ever represent, to differing degrees, an IoT system's claim upon a possible reality. By considering the ways in which potential is already an aspect of the value generation of IoT systems, I opened up value from a mode of representing a possible world to a question of the relation between the actual and potential. In the next section, I turned to Simondon's concept of the preindividual to establish an understanding of actuation as rooted in recurring virtual forces. To understand the implications of this for a social scientific view of actuation, as well as an IoT system as a whole, I finally turned to the concept of transduction, which accounts for the technical reality of IoT actuation as an operation that generates transformation and the very possibility of participation. With transduction and the ontogenetic potentials of thinking in mind, the final Claim will explore how an Internet of Things brings the very possibility of participation into existence — albeit partially.

Claim III

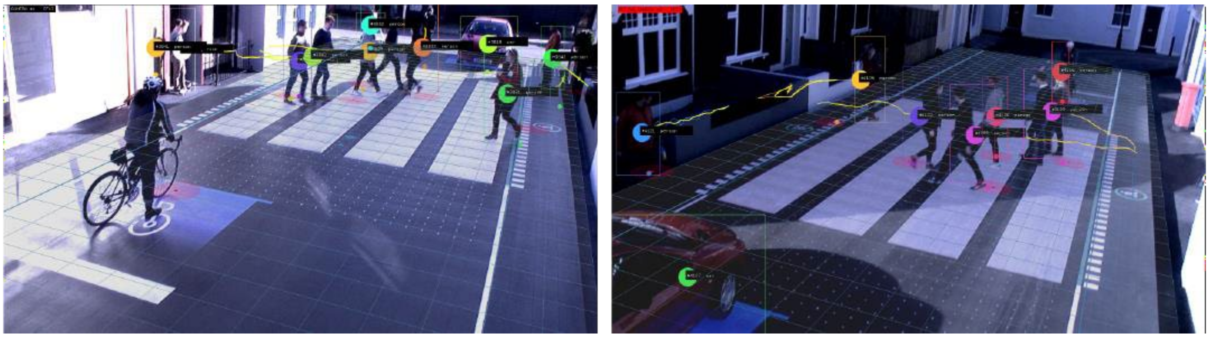
Crossing, exploring, dying

In this final Claim, I will examine five projects developed and delivered by Umbrellium, a smart city consultancy based in the UK. Using Internet of Things systems, Umbrellium responds to requests from city councils and private companies to "design and activate urban environments with technology" (Umbrellium 2021). Their goal, writ large on their website, is to "make cities work for everyone" (Umbrellium 2021). Civic participation has been a strong focus in their instalments — whether through a massive balloon sculpture that a crowd can control, an online search engine for IoT devices, or a "hyperlocal" radio for apartment blocks. They have been featured in numerous publications, conferences and architectural design awards for their highly engaging and aesthetically impressive installations and programs. "The thing that underpins all of this", said Usman Haque, the CEO and Founder of Umbrellium, "is the question of connectedness".

I interviewed Usman on the bottom floor of the London headquarters near the end of 2015, where he described Umbrellium's directive as creating "citizen engagement spectacles". Breaking with the classical understanding of the spectacle that involves an event and external, largely passive, spectators, Umbrellium's spectacles require participation from the spectators. Consistent with the focus in recent decades on participatory design and co-design, Umbrellium is oriented to spectacles in which "people feel startled on an urban scale, where they're instrumental in creating it" (interview with Usman Haque September 2015). Since our interview, Usman has branded this participatory design strategy as "mutually assured construction", which he described in a publication:

> I am interested not just to agree that we won't destroy each other, but more to use the consequences of apparent paradoxes or contradictions to be positively constructive together… Mutually assured construction is essentially a set of design strategies for building, deciding, and acting a future together, without requiring consensus on that future" (Haque 2018, pp. 41-42).

In other words, citizens who interact with Umbrellium's installations are encouraged to "connect beyond their usual sphere and to make collective decisions, enhancing their sense of ownership of the outcomes" (Haque 2017, p. 87). "What we're trying to do", he emphasized to me, "is build what I call a *shared memory of a possible future*". This phrase provides a starting point for analysing Umbrellium's methodology and its aim, which is to speak directly to the kinds of hopes and worries that preoccupy critics and users of the Internet of Things: how can the Internet of Things speak to the problem of belonging, of alienation, of safety, of citizenship? Or more broadly: how does technology enable us to relate? In the three projects described below, the answer to these questions arrives in the form of a claim: IoT actuation can *create change in a way that invites participation and generates value*.



Simulation of Starling Crossing in action. Images © Umbrellium 2020, with permission

Starling Crossing is a digital crosswalk that only appears when it is needed. “The pedestrian crossing is one of the most complex moments of interaction that almost everyone experiences on a daily basis”, Usman says in a 2017 interview. “It’s that one moment where you’re actually negotiating with others as well as potentially with big chunks of metal” (Haque in Mairs 2017). A section of street is laid with high-impact plastic panels. When cameras register an object approaching, on-site computers classify the object (as pedestrian, car, bicycle, and so on) with sophisticated machine vision. Once the object has been identified, lights mounted on the side of the road dynamically project crosswalk lines onto the street panels to light up a pathway and create stopping lines for oncoming vehicles. Similarly, if the network senses that two objects are on a trajectory to collide, warning lights will begin flashing around the object to increase awareness of the situation; for example, “if a child runs into the road unexpectedly, a large buffer zone is created around them to make their trajectory clear to any nearby drivers or cyclists” (Umbrellium 2021c).

Usman describes Starling Crossing as one of the few examples of a pedestrian crossing that is modelled on pedestrians, rather than vehicles: “rather than designing a road for cars, with humans as an afterthought, we're designing streets that respond to humans" (Haque in Ryan 2020). As such, agency is a significant emphasis in the Starling project, "aiming to enhance people's perceptual awareness without distracting them, and highlighting safety relationships between people and cars so they can make their own decisions, rather than telling them what to do" (Umbrellium 2021c). Moreover, the project adapts to patterns of agency. Taking a cue from ideas about desire lines and the way ants follow trails of pheromones, Starling Crossing can "monitor and adapt to pedestrian desire lines over long term use so that, for example, if most people exiting a tube station end up walking diagonally across the road towards a park entrance, the crossing is able to reconfigure as a diagonal or even trapezoidal crossing, with corresponding safety buffer zones" (Umbrellium 2021c).

While Starling Crossing relies on high-speed and highly adaptive actuation to transform pedestrians and streets into something new, the Pollution Explorer's Toolkit (PET) takes advantage of a slower and more deliberative actuation. PET was a series of interactive workshops, hosted by Umbrellium from 2017-2019, in which members of a community were given a new way to understand the air quality in their neighbourhoods. Each participant received a toolkit, including a thin plastic coat covered in air quality sensors, as well as paper-and-pen tools for making notes. They wear these self-tracking devices on a customized walk through their neighbourhood, which registers air quality and collects the data using a public IoT platform. As they stop at different points, each participant is told to raise their arms into different gestures to signal their personal perception of air quality: both arms up means Good Air, both arms down means OK Air, and both hands covering the nose means Bad Air. The sensor-covered coat registers these gestures for analysis and later comparison. In a later workshop, the air quality measured by the sensors at each point is compared to the air quality that each participant measured with their arms. The community is then led to discuss how each set of data converges and differs, and how this allows them to make sense of air quality in a new way. The process is called "perceptual experience mapping" (HackAir 2021).

Pollution Explorers Toolkit workshop and walking tour. Images © Umbrellium 2020, with permission

As the description reads, PET "empower[s people] to make sense of air quality issues and more importantly, act upon them through individual and collective behaviour change" (Umbrellium 2021b). Participants are encouraged to "make sense of the impact they have on the environment, share experiences and motivate each other in committing to tackling air quality issues through their own actions" (Umbrellium 2021b). At the end of the self-tracking period, participants are encouraged to write a postcard to Umbrellium about a behavioural change they have undertaken to contribute to a less pollutive future. Actuation in this project is present at the level of the self-tracking devices, though it is relegated more decisively to the human participants who are encouraged to lift their arms, make notes, talk to their neighbours and create behavioural change according to these communal interactions. According to one study, enabling citizen sensors to act on their data resulted in an average decrease of energy usage by 24%, and avoided the need for expensive infrastructural sensor systems (Crowley, Curry & Breslin 2013). PET reports similar benefits, both technical and social, including showing that "people's ability to assess the quality of air compared to digital sensors is very high, up to 75% accurate", and that as many as "90% of the participants have shown consistent dedication in committing to an action to tackle air quality in their everyday life over a period of 7 consecutive days" (Umbrellium 2021b).

PET map, workshop, and final postcard. Images © Umbrellium 2020, with permission

In giving texture to local and everyday experiences of air quality, PET is one instance of a current surge of citizen sensing projects in urban areas (see Coulson & Woods 2021; Mahajan et al 2021; Petersman & Suman 2021). Such projects aim to retrieve scientific modes of environmental sensing from institutions and distribute these methods into the community. Actuation is to some extent retrieved from the domain of policy making or scientific research, as participants are "activated" to perform critical interventions in response to the data they collect and log. The word "retrieve" is used very specifically here; although the specific methods of climate sensing may have never existed in the lay community to begin with (for example, novel sensors that can identify a pollutive substance at the level of parts-per-million), what such projects hope to return to the citizen is a sense of ownership, duty and care for a space that was otherwise put outside their control. Haque notes as much in an interview about city life, saying that "people feel that the city is somewhere they inhabit but don't control" (Haque in Ryan 2020).

The final instalment, Natural Fuse, is a somewhat morbid experiment on the connections between energy use, communal responsibility and selfishness. Between 2009-2015, groups of citizens in the same neighbourhood were each given a pot plant with a number of components: a self-watering system, a power plug to connect to a socket, a meter that reads their electricity use, an IoT node that communicates with other houseplants on the network, and a small vial of vinegar. Each day, the pot plant will water itself and sequester a given amount of CO_2, transforming it into oxygen. As its power plug is used, the amount of electricity drawn is translated into CO_2 units spent. If the day passes with little electricity used, the plants on the network generate an excess of oxygen, which can be supplied to a particularly intensive user.

Natural Fuse. Images © Umbrellium 2020, with permission

Natural Fuse comes with a tension, however: "even low-powered lightbulbs draw more power than can be comfortably offset by a single plant" (Umbrellium 2021a). If a participant on the network requests to use more electricity than can be accounted for by the network, the user has two options: to put the plant on "selfless" mode, which will only draw as much power as the CO2 sequestering supply allows — which means, effectively, that whatever has been plugged in may simply turn off. Or, the participant can turn the switch to "selfish", which allows the unit to draw as much electricity as needed. But if the CO2 sequester is completely exhausted, the system will trigger a "kill signal". One random person on the network will be sent an email (along with the offending user) to tell them that their plant has lost one of their three "lives". If any plant loses all their lives, it receives an injection of vinegar — killing the plant in a matter of hours.

“The point is that people’s decisions have a visceral impact on others in the community”, Haque says in a presentation (Umbrellium 2021a). If everyone cooperates, he explains, then the plants thrive and everyone benefits. If they do not, then plants die — not just affecting the owner of the dead plant, but also communally decreasing the availability of electricity for the network as another carbon sink is lost. Described as a “micro-scale carbon sequestering network”, the purpose of Natural Fuse is to provide a “circuit breaker” for “carbon footprint overload” by encouraging “cooperative behaviour change” (Umbrellium 2021a). Like PET, the purpose of this project is ‘empowerment’ through personal choice and cooperation.

Both PET and Natural Fuse are aimed at the problem of climate change and the ways in which cooperation can modify habitual modes of thinking about and acting on climate change, with and through technical assemblages. Usman sees climate change as essentially a problem of structures of decision making:

> Right now we generally have to abdicate our sense of decision making or responsibility to a media figure or a politician or a religious figure or even a scientist. Because we don’t really know what’s going on and so we throw our lot in with somebody’s opinion... What I’d like to see happen, and be enabled through these kinds of projects, is one where we question those standards of evidence... that we’re participating in some sense.

Participation, as Usman uses the term here, appears to fall into the category of collective citizen engagement described above. Usman was careful to clarify, however, that he did not believe that this kind of participatory democracy necessarily leads to a good outcome:

> Not that I think we're more likely to solve it if we all do it together or anything like that. I just feel like, if we're all going to go down, let's all go down together! It should be possible for us all to be a part of the questioning, where are the boundaries to this problem? What are the possible solutions? … In the future I would like to see, there would be the capacity to continue that struggle.

Usman's aim is to gesture toward a more open, process-based sense of participation. Having said this, it is not immediately apparent that the Umbrellium projects depart significantly from those "citizen activation" projects that have, since the Umbrellium projects of 2015, become the norm as ways to empower citizens to drive individual and collective change through co-operative participation. When Usman speaks of the project as an 'invitation' to participate, it is an image of the human as citizen that he evokes beside an ideal of participation modelled on participatory democracy, with IoT systems functioning to facilitate the realisation of this ideal.

No doubt, the project goes beyond the popular model of citizen sensing, the benefits of which are widely lauded by policymakers. While Gabrys and Pritchard (2018, p. 354) argue that, in some cases, "citizen sensing practices are reworking the sites and distributions of environmental monitoring toward other configurations that are more multiple and collective", they also stress that these are practices that are "in many ways structured as an individual pursuit." Yet, to the extent that Umbrellium transcends the individualist limitations of citizen sensing, I would argue that this is neither because it encourages citizen participation nor because it has the effect of producing collective change, both of which could be readily understood in representational and banal terms as the co-operative actions of always already individuated agents. As I argued in Chapter 5, seen from the point of view of technical mentality, participation is not something that emerges from a technologically mediated event of human participation but is, rather, the ontological condition for the ontogenetic encounter between technical and human mentalities. If, for example, Natural Fuse gives rise to the propagation of information between user, fuse, plant and community, such information is never merely the data that arises from the co-operation between already individuated things. In this respect it is important to recall Simondon's rejection of hylomorphic and substantialist modes of explanation, which invariably posit information as something essential, whether it belongs as an abstract form to matter or is extracted by thought from matter. In any event, it is never the principle, but the process of individuation, that takes centre stage in a Simondonian account.

To return to Starling Crossing, PET, and Natural Fuse: what they all share is an emphasis on community building through participatory human-technical relations, in which IoT actuation creates change in a manner that invites participation and generates value. Each project, then, straddles a tension between the production of new possibilities and the capture of these possibilities in individuations rendered as newly-empowered modes of subjectivation. The project's aim, as Usman indicates, is to rescue human agency from the technological in some sense, via a process of collective decision-making:

> I'm not sure that I could claim that technology helps you make a better decision. But I do think that it makes it possible to make a decision together… I think it's important for the crowd to be able to make some kind of self-determination in order, just in order to persist, to be sustainable. That we all make decisions together based on the fact that we're connected together… I guess what we're trying to counter is that so many IoT devices try and make decisions on your behalf.

Yet, we could equally argue that, in making perceptible the problematic tension through which value is produced, a more ecological perspective is produced than this kind of human-centred design paradigm implies. In making sense of Natural Fuse, for example, we might refer to Gabrys' explanation of the use of lichens by scientists as the "canaries in the coal mine" of climate change. As she stresses, lichens have the quality of responding to certain environmental factors with relatively straightforward expressions, making them useful and reliable bio-indicators over long periods of time. She describes lichens as "environmental subjects that attend to the lived effects of pollution" and emphasises that "lichens are more appropriately characterised as ecological microcosms, rather than as discrete and easily classifiable entities" (Gabrys 2018, p. 352). As she puts it, "(b)io-indicating lichens tune our attention to the relational qualities of organisms, which open toward more ecological configurations of entities" (Gabrys 2018, p. 352).

What interests me here is less the attribution of non-human agency than the fact that the ecological perspective rests on the non-representational capacities afforded by the lichen; lichens do not quantitatively *report on* the pollution in an area, but rather their growth and patterns *express* "the spread and accumulation of pollution in particular sites" (Gabrys 2018, p. 358). These patterns may well be reduced to quantitative indices or systematically turned into a measure of environmental change and effects, but Gabrys pushes the use of lichens in more processual directions. She shifts the discussion towards the entanglement of the lichen with its environment (and vice versa), arguing that bioindication itself

> …highlights how pollution — as an environmental conflict — becomes entangled with the specific material transformations and incorporations of organisms in their habitats. … Pollution is less about a numerical value, and more about an ongoing set of transformative effects that even rematerialize and remake environments (Gabrys 2018, p. 360).

The sensing performed by lichens, and the transformation of their sensations into their various vegetal forms, thus constitutes a "speculative bioindicator garden" (Gabrys 2018, p. 365), with the potential to "generate new modes of encounter together with new propositions for ways of being" (Gabrys 2018, p. 362). Gabrys sees in this speculative collectivization a new image of the environmental citizen as "an environmental entity or bundle of entities", rather than a "responsible consumer-subject amenable to behaviour change" (Gabrys 2018, p. 356).

It is clear that the stated goals and methods of PET and Natural Fuse are decidedly less speculative than this, and PET and Natural Fuse focus on reconceptualizing the place of the subject in pollutive processes and milieus towards the broad goal of individual and collective empowerment. Starling CV, PET, and Natural Fuse nonetheless pose the human-technological relation as a persistent and felt question: what are the technological conditions of the social, and the social conditions of the technological, and how can these conditions be expressed through collective human-technological acts? Umbrellium's civic Internet of Things installations are attempts at making such acts appear as questions rather than declarations and, as processes, these projects have at least the potential to produce novel modes of participation that are not directed solely at the generation of value. Nonetheless, the technical mentality tends to remain as something of an "obscure zone" (Simondon 2017, p. 248) in these projects. As Lindberg (2019, p. 300) argues, Simondon's contribution is to understand "the technical object as support and symbol of the transindividual relation." Lindberg (2019, p. 300) goes on:

> Being the *support* of this relation, the object is precisely not the *foundation* of a community but the intermediary of *transindividual* relations. The relation it mediates is transindividual, that is to say, it does not connect already constituted individuals but expresses the preindividual reality thanks to which individuations can take place. But technical objects do not only enable human being-with: They are also something with which human beings exist, so that human beings are engaged in specific ways of being-with-technical objects.

Or to put it in Simondon's own terms:

> …man is the permanent organizer of a society of technical objects that need him in the same way musicians in an orchestra need the conductor. […] Man thus has the function of being the permanent coordinator and inventor of the machines that surround him. He is *among* the machines that operate with him (Simondon 1958, cited by Lindberg 2019, p. 300).

As I have emphasised, the human's being "among the machines that operate with him (sic)" is not the "being among" of discrete entities but a kind of collective process of individuation. As we will see, the Simondonian notion of "transindividuation" is crucial in making sense of the ontogenetic character of such processes.

Bubbles and lasers

Thus far, my concern has been to accentuate and emphasize the technical reality that often goes missed or misunderstood in accounts of the Internet of Things. Human life and other lifeforms have always been a part of this reality and it is with an eye to this fact that I have tried to weave the meeting of the living and the non-living through my accounts of communication, sensing and actuation. Simondon has been especially suited to this aspect of my project, as his positing of a fundamental interoperability provides a method for considering the integration and co-individuation of a multitude of beings, especially human and technical. But there is, admittedly, a major aspect of Simondon's work that I have so far neglected; namely, his significant theorization of human subjectivity, modes of collectivity and transformation. Simondon develops a theory that attempts to bridge the gap he felt so keenly between the technical and the available modes of human belonging to participate in it.

There has been little need for this dimension of Simondon's work so far in this thesis, nor will I attempt to summarize or encapsulate the whole of it in this chapter. I will, however, take something of a detour into Simondon's theorization of *the transindividual* to reflect on two more Umbrellium projects. My motivation for this detour is a concern with addressing how the technical reality of an IoT system, which I have gone to pains to emphasize and reconsider, is not merely an addition to a pre-existing social reality, but is in fact a constitutive aspect of that reality's unfolding and, what's more, generates structures of individuation for collectives by merit of its metastable interoperability. The relative openness of the following two projects, compared to the more instrumental goals of citizenship, safety or environmentalism in the previous section, allows for a more speculative reading of their functions, and makes some room to meditate on the human more deeply than this thesis has thus far considered.

Considering the human-technical relation according to a processual framework requires, firstly, acknowledging the constitutive and cohesive role of the technical in vital collectives. Simondon's concept of the transindividual arises from the notion that collective relations are mediated by technical ensembles and processually held together by transductive operations. Individuals require collectives because they can "address problems that psychic individuals are unable to", Grosz (2012) argues; "they create a mode of higher-order resolution and utilization of the tensions that remain unresolved from the preindividual" (Grosz 2012, p. 50). Transindividuation is a term that designates "individuals [existing] together as elements of a system that contains potentials and metastability, expectations and tension", and the discovery of "a functional structure and organisation, which integrates and resolves the incorporated, immanent problematic" (Simondon 2017, p. 294). Transindividual relations are not based on what may separate or what may be identical between living beings, but on "preindividual reality, this weight of nature that is preserved with the individual being, and which contains potentials and virtualities" (Simondon 2017, p. 253). Considering that technical objects are a constitutive part of the collective, then the ability to discover a mutual structure and organisation — to participate in each other's preindividuality, as it were — thus relies on the integration of human and technical activity. Collectives, then, are temporary unities of transindividual relation composed by the integration of vital and technical activity.

In this scheme, technical objects do not simply provide a resource for collectivisation. Technical activity is, in fact, "the model of the collective relationship" itself (Simondon 2017, p. 250). Simondon goes on to clarify that technical activity is not the collective's only mode of being, but it is firmly of the collective "and, in certain cases, it is around technical activity that the collective group can arise" (Simondon 2017, p. 250). Reconsidering the human thus amounts to a reconsideration of technical activity itself. This, Muriel Combes (2013, p. 78) argues, is one of Simondon's greatest virtues: to have the foresight to grasp post-industrial technicity as that which "now constitutes a milieu that conditions human action". Furthermore, this means that the terms on which the human collective and technical activity can relate is a relatively 'simple' matter:

> Out of that milieu, we need simply to invent new forms of fidelity to the transductive nature of beings, both living and nonliving, with new transindividual modalities for amplifying action. For, in our relation to preindividual nature, multiple strands of relation—to others, to machines, to ourselves—entwine in a loose knot or node, and that is where thought and life come once again into play (Combes 2013, p. 78).

In other words, and as gestured to in the previous three Umbrellium projects, what is needed for reinventing the human-technical collective is an effort to invent new modes of relation. Starling Crossing could in this light be read as propagating a configuration of urban space that has greater fidelity to the relation between pedestrian, city and road; PET could likewise be understood according to a new fidelity between the sensory relations of the human body and the individuations of pollutive substances; and Natural Fuse as encouraging a greater fidelity, and a new, deadly relation between the flow of electrons into a house and the flow of carbon across a vegetal network. The emergence of collectivities in these projects is not simply made possible by the availability of an IoT system, but rather the integration of human and technical activity *is itself the mode of the transindividual relation*. In other words, interoperability is the Internet of Things' mode of operation that brings strands of vital and technical activity together into knots. We will now explore *Burble* and *Assemblance*, our final Umbrellium projects that literally illuminate interoperability as a mode of collectivity in a post-industrial milieu, and how their luminous knots point towards a more problematic basis for the human-technical relation.

Burble in Paris and Salford. Images © Umbrellium 2020 with permission

Burble and *Mini Burble* were interactive balloon displays, performed for a few nights at a time, between 2006-2015 across the UK, Europe, and in Southeast Asia. On the day of the performance, a fine mesh net, doubled over and sectioned into squares, is laid on the ground above which Burble will fly. Within each square a white balloon is placed, its insides fitted with a wide-colour-spectrum LED and small radio transmitter. As night descends on the installation, the balloons are blown up one by one and raise the structure into the skyline. Touchscreens are provided on location, showing a grid of white squares, with each square corresponding to a single balloon. To interact with Burble, a member of the public could take up a touchscreen and draw on the grid, "like finger painting" (Quays Culture 2015), to light up Burble into a gradient of colour. In later installations, spectators could also interact with Burble via Twitter, with the hashtag "#burble" followed by a colour, which would blanket the whole display with that single hue. "Most of us think that the skyline is something created by others," Usman says in an interview. However, "Mini Burble is about opening that up so that members of the public can actually do something that can change their skyline, albeit just for a few nights" (Quays Culture 2015).

Assemblance was a continuation of Umbrellium's fascination with structures of light. Similar to Burble, Assemblance was a public interactive display, a "collaborative immersive environment" that incorporated a lightshow and physical engagement with a grand sculpture (Umbrellium 2021d). Laser light projectors were mounted in the ceiling of a dark room — across the UK, Sweden, and Greece — and projected directly down onto the floor in beams, strobes, tubes, and pyramids of colour (Umbrellium 2021d). Gesture tracking software mounted onto the projectors allowed visitors to interact with and change the shape of the light sculptures. Pipe-shaped beams could be pushed or kicked and made to swing; pointing up at the ceiling could call down a curtain of blue around the pointer and be banished again with a flick of the arm. All installations could be interacted with by multiple people at once. In fact, the manner in which visitors gestured with the light structures determined their strength and stability; though what configuration of bodies would lead to the strongest light show (and in some cases, unlock 'easter egg' surprises) could only be discovered by experimenting with others.

Assemblance. *Image © Umbrellium 2020 with permission*

As with PET, Natural Fuse and Starling Crossing, these projects provide opportunities for a mode of collective participation that exceeds the more reductive applications of IoT systems as generators of democratic or citizenship value. Actuation is the point at which this participation becomes possible. However, unlike the previous projects, Burble and Assemblance foster a participation that is not directed at any particular signification of the individual, whether as energy user, responsible pedestrian or citizen scientist. The aim of these projects is, rather, participation itself and, I would suggest, not merely the participation that would posit pre-given individuals as its ground. The groups which are formed in Burble and Assemblance are temporary collectives that emerge out of a process of relation — to other bodies in the dark, to the populated skyline, to the creation of bright light sculptures and undulating spheres of colour. What constitutes these transient groups are not single individuals brought together, but rather, as Elena del Río puts it, "pure relationality" (del Río 2019, p. 60).

What role does the Internet of Things have here, in this pure relationality? Technical objects are supports and symbols of the transindividual relation; they mediate disparity into a temporary metastable unity. Thus, technical objects are not the "*foundation* of a community but the *intermediary* of transindividual relations" (Lindberg 2019, p. 300). What Lindberg describes as intermediation, I would equate to interoperability, and the requirement for disparity and excess that I have emphasized throughout this thesis. Thus, the very mode of being of the Internet of Things *is interoperability itself*. Furthermore, this means that every IoT system may inaugurate a process through which transindividual relations and collectives can arise. I would then argue that Assemblance and Burble, in this case, are singular instances of interoperability through which transindividuality arose. If the human is the 'conductor' and 'interpreter' of the technical ensemble, then the Internet of Things illuminates this in its interoperability. The Internet of Things is the crystallization of human gesture. In

Simondon's words, the human "resides in machines", in the form of "human gesture", "fixed and crystallized into working structures" (Simondon 2017, p. 17, my emphasis). Interoperability is itself a human gesture that requires an initial disparity, and it is this disparity that opens up the human to interoperability; that is, to relationality itself.

This is not to imply that 'pure relationality' constitutes a necessarily preferable state of affairs, nor that Burble and Assemblance could not be put to this or that end of citizen engagement, or taken up as projects that give the appearance of de-privatising the city without actually dismantling underlying forms of ownership. Yet these ends, while possible, are not inevitable, and to point to their abstract possibility would be to ignore the real potentiality in which they are involved. The next and final case study addresses real potentiality, and the ontogenetic disparity it entails, as fundamentally 'fuzzy'.

Fuzzy things

Back on the farm. Sitting around his kitchen table, cups of instant coffee between us, Tom Gunthorpe was explaining where he feels the future of agricultural technology is heading. “Have you ever heard of fuzzy logic?” he asks. Fuzzy logic, he explains, is the theory that logical thinking happens in a fuzzy, non- regimented, non-atomistic way. He gave the example of driving in a car, at twilight, while it’s raining. “How fast do you go?” Your choices around deciding how fast to go, he explains, are based on a number of factors — the twilight visibility, the slickness of the road after the rain, the proximity of other cars, the speed limit sign which you passed many kilometres ago — which do not present themselves as certain quantities, but rather as “fuzzy” elements which culminate in an equally fuzzy decision and action. You change your speed according to how these elements present themselves as you drive, equally fuzzy in their emergence and in the way you make decisions based on when and how they appear. AI and machine learning, he argues, tries to do that on the atomic level - meaning, with a series of definite and finite decisions based on a particular moment in space and time. This atomistic approach, Tom argues, doesn’t reflect how we actually make decisions. For Tom, the process of making good decisions in technologies is not a matter of infinitely precise measurements or understandings of the world; it’s about efficiently replicating the kind of fuzzy processes which characterize real decision making. “Life is fuzzy”, he says, waving his hand over our coffee cups and out into his paddocks.

The talk of fuzziness was an interesting development in our conversation, considering how he had earlier been talking up the potentials of more precise knowledge about livestock, their movements and qualities over time, about how these forms of knowledge are necessary for knowing which part of the flock to weed out. But it is not contradictory. Gunthorpe is proposing that these technologies will enter into the relation between humans, animals, agriculture, paddocks and markets in a way that is striving towards the incomplete, inchoate processes which actually produce life, which are endlessly changing as the milieu changes, and which continually shift towards something else. Though the Internet of Things may be primed, pursued and produced at the level of the exact, it also creates opportunities to participate and intervene in the fuzziness of living.

Fuzziness seems a rather fitting concept to close my final Claim. First, it is important to distinguish between the way that fuzzy logic has been used within the social sciences, and how I might use it here in a processual way. When fuzziness has been applied in the social sciences, it has been used to address the "grey zone" of social behaviour (Winter & Kron 2009) by providing a conceptual and mathematical model for objects and states whose boundaries are uncertain or cannot be reduced to a yes/no condition. The membership of individuals to a group, for example, can be considered "fuzzy" when membership is a matter of degrees, or the boundaries between member and non-member is porous. These "fuzzy sets" allow for a more nuanced understanding of transient phenomena like homelessness, or political belief, or mental illness, for example. Even individuation itself can be understood as a fundamentally fuzzy process, progressing by way of degrees, according to Juliano Neves (2020) in his application of fuzzy logic to Simondon's notion of ontogenesis. Fuzziness, Neves (2020) argues, lies explicitly at the borders of mathematics, an observation that he relates to Simondon's claim that, for the non-living, individuation happens exclusively at the edges of the physical individual; like the crystallization that happens at the edge of the germ in a saline solution, the machine only individuates in response to its external milieu. Clearly, however, the flat application of fuzzy logic to socio-technical assemblages that include vast arrays of living and non-living individuals, cannot be adequate to understanding the transductive relations that would ensue. The mathematical application of fuzzy sets to social life may be accurate in a very fuzzy way, but even this is to reduce fuzziness to a kind of partial representational fidelity, which is incapable of addressing the real circulations between the preindividual and the actual.

I am interested in the ontological implications of engaging with the IoT through the operation of fuzziness to the extent that it indicates the much less representational sense of fidelity I referred to above, to signal an adequacy to the indeterminacy — yet determinability — of the preindividual field. Though Simondon never discussed fuzziness explicitly (at least not in any English publications to date), he did discuss quantum physics, to which fuzzy logic is related. In *The Position of the Problem of Ontogenesis*, he argues that quantum physics is the only field of scientific research that "grasps this regime of the preindividual that goes beyond unity", as it is capable of theorizing the exchange of energy between particles as a tension and operation that is individuation itself (Simondon 2009a, p. 6). Particle and wave theories, defined by their incommensurability as “the continuous and the discontinuous”, could “finally converge” as “two manners of exposing the preindividual” (p. 7). The preindividual is exposed as “the quantum and the metastable complement (the more than unity)” (p. 7).

Fuzziness in individuation, then, could be described as its excess. This directly contradicts the common presumptions around technological decision making; namely, that fuzziness indicates a lack. Instead, from a processual standpoint, fuzziness indicates the immanent and immense excess of the technical object and its individuation, which produces decisions only as one possible mode of its existence. A living individual cannot be exhausted by a given individuation. If it is exhausted, it dies — just as an excess of alcohol in the bloodstream exhausts the liver’s operations, followed in varying succession by the heart’s, the white blood cells’ and finally the brain’s. The non-living individual, the machine or technical object, also engages in fuzziness but only for a moment, and only at its edge. It is on the basis of this fuzzy edge that an IoT system can become interoperable withother systems, living and non-living alike.

Fuzziness, then, is perhaps another way of understanding the human-technical relation as Umbrellium has tried to foment it, and in the way Tom so avidly pursues. Fuzziness is what keeps the preindividual in sight. It is not just a technical condition that keeps the Internet of Things generative; it is also a mode of participation between human and technical systems. Understanding that participation happens on the basis of excess, rather than on the basis of identification, may not lead to “solutions”, as Usman puts it, but may in fact enable new problematics, disparities and heterogeneous tensions to arise, which are solutions of a different kind.

6
Conclusion

Three machines open this thesis: the winding materiality of the Internet, the bright immateriality of wifi protocols, and the curious, grabby endeavours — social, ideological, epistemological, commercial — that capture these machines. The Internet of Things, I argued, brings these machines together into a coherent mechanism. By opening with these three machines, and by posing the Internet of Things as what binds them, I wanted to establish from the outset that the technical objects and ensembles of our time require attention that is far more processual, operational and functional than common discourses would have it. Internet of Things systems create new ways to understand, interact with and participate in the transformations of the world. They do this through their technical operations, which are transformative in themselves, and they make these transformations available by communicating and sensing the world in such a way that it can be acted upon. IoT systems actively participate in the becoming of the world by modulating its operations, concretizing its expressions, and transducing its potentials.

In this thesis I have worked through the pre-eminent preoccupations about the operations of IoT systems, how they culminate into common concerns, and the ontological and political implications that follow. At each turn I unearthed the representationalist assumptions that often motivate these concerns; most commonly, the presumption that the function of technology is to differentiate between true and false claimants on reality. When approached from this set of assumptions, the Internet of Things is inevitably judged against a given image of the world and against the ideals through which moral and political judgments of that world are made. To rethink the Internet of Things as processual is not to deny the representation of, nor the form of, technical activity; instead, it is to subject such representations to a more rigorous analysis of the claims they sustain and to open forms to the operations that in-form them. I have deployed Simondon and other processual thinkers to push the idea that, as a framework for thinking, processuality opens up an ontological reality that allows IoT systems to be thought in accordance with their technical reality. More specifically, a processual philosophy grasps the technical reality of the Internet of Things as an ontogenesis.

One obvious motivation for considering the Internet of Things on its own terms is the fact that the claims and values with which it is associated profit from its processual character. Yet the question of the yet-to-be-actualised potentials of IoT systems is a more open and perhaps more interesting one. The previous chapter closed on a somewhat hopeful note regarding the social potential of the Internet of Things, given that we grasp it in terms of the processual character of its technical reality. To round off that note, briefly revisiting the arguments made throughout the thesis might enable us to give nuance to these efforts to gesture towards the potential of the Internet of Things and, hopefully, future technical ensembles like it.

Throughout the thesis I have critiqued representationalist accounts of the Internet of Things (and of representationalist thinking in general) which would assess it on the truth and falsity of its claims, and which would judge its ability to participate in human life according to its ability to mime or approximate human capacities — in other words, to be a "smart" technology. Instead, I have posed a processual ontology as an alternative approach that can examine the claim-making operations of communicating, sensing, and actuating, without subjecting it to the realm of the true and the false. Truth and falsity animate the world of representation, but they do so on tired and somewhat inadequate terms. When constrained by the requirements of representation, social theory is poorly equipped to account for the mutually constitutive and transformative relations between human and non-human individuals and the processes of individuation from which such individuals arise.

The concept of interoperability emerged from such a critique to figure as a major theme in my efforts to reconceive technical reality beyond the determination of utopian and dystopian discourses alike. Firstly, communication was shown to be based in disparity rather than similarity, and it was stressed that it is this disparity itself that enables heterogeneous systems to come into connection, creating the conditions for interoperability. Secondly, sensing was shown to be an operation of interoperability, being a function of the integration of disparate layers of reality and creating the conditions for new structures to appear. Lastly, actuation was shown to be an operation that brings these new structures into reality and the point at which the interoperability of human and technical individuations is most clear. In short, interoperability is not just a "feature" of IoT systems, as common discourses would have it, but one of the very modes of their individuation. By investigating interoperability as a mode of the *becoming* of the Internet of Things, those discourses that would reduce communication to connectivity, sensing to intelligibility, and actuation to value, are shown to lack an appreciation of its technical reality. Not only do the operations of an IoT system exceed their representational forms, but it is by merit of their excess that interoperability becomes possible.

Excess, then, is a second major theme that emerges from this work, most notably in the empirical explorations. In each case study, the claims pursued and produced by IoT systems were greatly eclipsed by their participation in diverse potentialities. In Claim I, the vagaries of "smartness" outweighed the expectations of connectivity often promised by IoT systems and those who install, develop, champion and maintain them. Smart boxes, in one case, produced an excess of modulation through which both the labour of networking and the human-technical relation became possible. In another case, the promises of connectivity arrived as an excess of the human itself, decomposing the technical ensemble into a city of modulated processes of subjectivation. A final reflection on the invention of smart objects demonstrated that, despite the ability of such objects and their proceeds to be captured by the demands of smartness, their relational capacities far outstrip what a representationalist focus on connectivity could rightly claim. Claim II explored the ways in which sensing ensembles, when introduced into a milieu, transform the potentials which are available to them; a tag reader enables new methods of managing life, a smart building dynamically illuminates the incommensurabilities of the living and the non-living, and a soil moisture sensor network generates excitement, joy, and impenetrable mystery. These potentials were not residing in the draughter, building or Arboretum, as if awaiting discovery (as the focus on intelligibility would have it) but became possible at the sensor networks' margins of indeterminacy, at the very point at which that which is sensed escapes and exceeds the technical object. Finally, as explored in Claim III, the potential to use this excess to generate novel structures and ways of being in the world only becomes possible at the moment the IoT system finds a foothold in a greater ensemble — namely, the human activity in which technical reality subsists (and vice versa). In short, the technical operations of the Internet of Things habitually *exceed* the capacities ascribed to them, and it is in this excess that attempts to remake the human-technical relation should refer.

To this end, a transformation in the social scientific habits of thinking about the Internet of Things, and technical objects in general, is crucial. Throughout this thesis I have analysed habitual modes of thinking about the Internet of Things, whilst ushering our discussion away from these ready-made assumptions. However, this was not to imply that habit itself is morally or critically vacuous. As many have already shown, habit itself is precisely the gateway through which common configurations — between human and machine, body and thought, theory and practice — can be opened up to new potentials and possible relations (see Southerton 2017; Manning et al 2019). Hynes and Sharpe (2015) especially emphasize the way in which habit is a mediation, a "creation of space" that engenders "material dispositions" which "affirm the intensity of the present" (Hynes & Sharpe 2015, pp. 67, 80). Material habits and their incorporeal forms have been explored throughout the thesis, appearing in the modularity of communication and the transformations rendered by sensing and actuation. Thinking itself was one of these habits, and was shown to have its own material and processual basis, appearing in cognitive schemas, technical mentalities, and regimes of participation. In his later writing, Simondon described thinking itself as a force of individuation — thinking has the ability to solve problems for the living, as much as digestion solves the problems of the stomach, or labour solves the problems presented by a community. When thinking is understood as individuation, then the attempt to find a new way to think through the Internet of Things becomes a more critically important activity.

My contention has been that the major mode of thought regarding the Internet of Things has persisted in the form of *the claim*. By pursuing this question of the claim of the Internet of Things in my analysis, I did something which was in certain respects un-Simondonian. As Simondon (2009, p. 10) insists in *The Position of the Problem of Ontogenesis*, an approach based in individuation requires a new method of inquiry, specifically one that does not attempt to "compose the essence of a reality using a conceptual relation between two pre-existing extreme terms". Analysing IoT systems as I have done has involved, to some degree and for analytical purposes, posing "claims" and "IoT systems" as pre-existing terms. Yet the point has not been to solidify my object or its character. Rather, it was the *tension* between the representationalist claims about IoT systems and the processual aspect of their operations that I was most interested in exploring. And this tension is, I believe, one of the Internet of Things' constitutive conditions of possibility. Ultimately, this is the claim's mode of individuation when unyoked from a history of representationalist thought: a source of tension between two heterogeneous orders which, to remember Sauvagnargues' formula, generates its own resolution.

With an eye to pushing the thesis towards future problematics, one could ask: what are the ways that excess and interoperability could be *felt and pushed*? It is not merely experimental uses of the Internet of Things that open our thinking to this question, though the projects covered here certainly highlight the excesses of IoT systems as points of interaction. As I have shown throughout my Claims, even the more palely instrumental systems, such as the ear tag or a box, propagate potentiality. This is not to say that fostering potentiality is a goal *per se*; as I have argued, potentiality can, for example, be turned towards the most banal interests of capital as easily as it may resist it. If the Internet of Things offers more than simply a new set of social, moral and technological problems to solve, but rather an opportunity to rethink the way in which technologies create problematics of thinking, then the margins of these problematics are where social scientific and philosophical interventions will find best purchase. Adequately *thinking* the claim-making powers of the Internet of Things requires an encounter with the provocation provided by its *technical reality*.

My aim — my hope — was to rescue our understanding of the technical reality of the Internet of Things from the hold of a thought that reduces it to that which is given, and thus fails to grasp its ontogenetic capacity. By exploring the unique capacities of IoT systems across Australia and overseas, and by discussing in depth the basis of IoT operations in process, I hope to have at least gestured toward the possibilities of more potentialized forms of participation in a more technically integrated reality. In any event, while we do not know what individuations are yet to come, my hope is that a sense of their immanent reality has been imparted upon the reader.

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