Unrepresentable: Technological Futures, Art and The Ontological Singularity

A thesis submitted for the degree of *Doctor of Philosophy* in Art and Computer Science.

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Declaration

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work.

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Summary

This thesis examines the implications of the increasing prevalence of computation in contemporary society. In doing so the thesis develops a definition of computation that is based on the manipulation and communication of abstract representations rather than specific technologies. As such this expanded definition allows the thinking of both human and machine practices as computational based on their relationship to abstraction. The thesis traces the route of this expanded definition of computation through the history of measurement practices to the present day in which abstraction in the form of data has become a dominant feature of contemporary society.

The thesis examines the work of artists and theorists who have attempted to examine change in society brought about by computation. In doing so the thesis groups these attempts under three categorisations that relate to their specific focus rather than by disciplinary boundary. Thus the thesis highlights the need for a focus that crosses these areas of concerns and that pays attention to the abstract basis on which computation is built.

By highlighting examples of abstract representation across contemporary society the thesis demonstrates the increasing dominance of abstraction as the primary site of engagement by individuals with the world and with each other. In this way the thesis shows how interaction with the abstract representations of computation gives rise to an increasing abstract construction of society. Through an examination of the functioning or representational systems and the interaction of memory and subjectivity the thesis proposes a mechanism by which this increasingly representational way of knowing is constantly reproduced. As such the thesis highlights the incompatibility of the abstract knowledge of computation with embodied and affective knowledges.

Finally, the thesis suggests that art practice is a useful and necessary tool for understanding the implications of computation on contemporary society. Through an examination of the concept of multiplicity and in particular by highlighting the differences between discrete and continuous multiplicities the thesis suggests how art practice functions through the production of subjective knowledge that requires for its completion difference and individual subjectivity.

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Preface: The Ontological Singularity

…In that Empire, the Art of Cartography attained such Perfection that the map of a single Province occupied the entirety of a City, and the map of the Empire, the entirety of a Province. In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it. The following Generations, who were not so fond of the Study of Cartography as their Forebears had been, saw that that vast Map was Useless, and not without some Pitilessness was it, that they delivered it up to the Inclemencies of Sun and Winters. In the Deserts of the West, still today, there are Tattered Ruins of that Map, inhabited by Animals and Beggars; in all the Land there is no other Relic of the Disciplines of Geography.

Suárez Miranda, Travels of Prudent Men, Book Four, Ch. XLV, Lérida, 1658

Having failed in my efforts to completely determine a unit with which the earth might be so perfectly measured, I left Valencia for that Empire in which the art of cartography, to which I have forever been tied, had at one time achieved its purpose of perfection. The truth, however, is that I was prepared to shed tears fearing the loss of the great achievement that our esteemed predecessor Miranda had reported. I thought to set out to the farthest reaches of the Empire, to assuage my failures on the Meridian mission and to recreate the perfect map from the fragments that remained.

On my arrival I found that such fears were misplaced and that my Repeating Circle, compass and log books would not be required. For I saw that no new map could be drawn of the Empire that would not simply be a facsimile of the last. To my surprise I stepped from the boat directly onto the surface of the map itself. Its completeness and detail was a triumph beyond which I could not have imagined. And yet my wonder at the map was soon overtaken by a wonder greater still. Fearing at first that I was suffering some ill effects of travel I checked my eyes and the faces of those inhabitants whom I met. Having contented myself that I was not being deceived, I realised that the inhabitants of this great Empire were fully unaware that the ground on which they stood was that which their eminent cartographers had previously drawn.

Pierre Méchain, Further Travels in Search of a *Base du System Metric*, 1805

Afterword: The Ontological Singularity

The Ontological Singularity is a thought experiment that allows us to think about the current state of technological practices and social practices related to technology. In many respects it is a type of mythology, a way of trying to think about where we are and where we are going. There is no sense in futurology or trying to predict the future from the past. Instead, the idea of the Ontological Singularity is a way of trying to find a way to address insights and concerns around technological development.

Creating the idea of the Ontological Singularity is, to intentionally misuse the words of Audre Lorde, a way of naming the unnameable so that it can be thought. The reason the word “unnameable” is used in place of Lorde’s “nameless” is that thinking about the future is virtual; it has no guarantees, it is not an actual thing that it hasn’t been given a name, but rather it is an insight to be worked out. The Ontological Singularity is not something that sits in the definite future waiting for its time to come into existence, Instead, it is one of a myriad of possibilities that we bring into existence through our actions and our decisions. To think of the future in this way, as made of an infinity of virtuals that can either be brought into the actual or which will disappear as unrealised possibilities is at the centre of this thesis and the practice that accompanies it. At each moment our decisions and our actions alter the field of virtuals, changing that which might be, altering that which can at some point become actual.

This thesis uses the Ontological Singularity to wonder how the technologies of the present and the immediate future alter the field of virtuals. How do the technologies and practices of today act to extinguish the virtuals of the future. And so in this thesis, the fiction and the practice are all an attempt to find a way to gather insights about current practices and the histories of technology together in such a way as to imagine where they lead. The Ontological Singularity is not a fact, it is not the logical conclusion of where we are going or the predetermined outcome of our actions today. Instead it is an attempt to address concerns and anxieties about what our current practices mean for the possibilities of our future. And so if the Ontological Singularity is a way of exploring an insight into our current practices then the thesis explores these insights in detail through the histories of their technologies, their uses and their limitations.

1 Introduction

How do we understand the implications of an increasingly computationally constructed society? How do we understand a world in which relationships between things are increasingly mediated through the structures of computation? How do we understand the impact of these changed relations on our ways of acting with and in the world? Whilst there is much on-going and recent research across subject and institutional divisions that attempts to answer these questions - this visual arts practice-based thesis identifies and explores a gap in the existing theories and artistic practices in their analysis of contemporary society and its relation to current and recent technological developments. In particular, this thesis examines the way in which computing technologies are structured around the production and transmission of abstract representations whose relationship to the non-abstracted entitles they represent is governed by a strict set of encoding ontologies. In doing so this thesis contributes a new understanding of computation that is defined by the relationship between the physical[1] world and its abstraction and highlights how these abstractions admit struggles for power and authority (*2 Representation: A Critical Background*). Furthermore, through an examination of art practices and theories that seek to examine the impact of computing technologies in

[1] A note on terminology: The terms "physical" and "real" are used throughout this thesis as a complement to the abstract entities of computing technologies. In this sense, physical is that which exists within the world "outside" of the abstraction of computation. In using this term it is accepted that many of the things to which it refers do not have material manifestations, for example concepts such as preference or happiness have no material manifestation but nonetheless exist in some form within the body-brain assemblages that make up individuals. Furthermore, it is also accepted that the abstract representations of computation exists upon some physical substrates, however, their physical instantiations on, for example hard drives, are seen as different from the functional instantiations as representations. In the same way it is accepted that abstractions are real.

society, this thesis contributes a review that gathers art practice and theory together based on thematic focus rather than disciplinary boundary – doing so it highlights the need for a focus that accounts for the importance of abstract representation as a key element of computation (*3 On the Structure of Posthuman Technosocieties)*. Through an examination of current practices in technologically advanced societies the thesis identifies the increasing importance of abstract computational structures throughout society and proposes mechanisms by which a logic of computation tends to cause a convergence of subjective understandings to a universal ontology (*4 The Convergence of Representation and Being)*. Finally, the thesis develops a proposal for understanding the implications of this increasingly computational construction for society beyond that which currently exists - in particular the thesis proposes visual arts practice as a way of communicating that encourages subjectivity and difference (*5 Unfolding and Entanglement* and *Unrepresentable – A Séance for Pierre Méchain)*.

The thesis proposes that there exists a current trend of convergence in our understanding of that which is represented through computing technologies and those physical entities to which the representations pertain. To understand the current state and trajectory of this convergence this thesis posits its endpoint as the "Ontological Singularity". The Ontological Singularity is speculated as a point where all knowledge and being are constituted through a single unified ontology[2] and where existence and representation within this ontology are coincident to each other. In other words, the Ontological Singularity is a point in which all entities and the relationships between them are mapped within a single strictly encoded ontology shared by all human and machine

[2] A note of terminology: In information science an ontology describes the definition of categories, properties and their relationships within a domain. In other words an ontology is the mapping of all entities that comprise the domain. In philosophy, where the term is more commonly understood, ontology refers to the study of the entities of existence and the relationships between these entities. Within this thesis ontology is used as a hybrid of these terms, or more correctly, as a contraction of these terms. Here an ontology is given to the understanding of the entities of the world by an individual, by a group or as a structuring of entities within an encoding and decoding schema.

actors. Through this proposal of the Ontological Singularity the project proposes that the increased understanding of the world through the representational technologies of computation present a challenge to the understanding of the world in ways that differ from those which can be encoded through computation and in ways that differ from the chosen forms of representation that form a global ontology for the representation of phenomena.

The thesis utilises the Ontological Singularity as a speculative point at the end of a process of convergence. This strategy is employed in order to highlight the importance of projecting the current trend towards its outcome such that the effects currently produced and those in the future can be thought of in terms of trajectories rather than as discrete elements of an indeterminate sequence. In other words, the thesis projects forward to the Ontological Singularity as a way of tying together threads that are common in the current practices across diverse areas of life. In this way the thesis is a reverse aetiology of the present condition of society – it projects the present from the future. The process of this convergence is identified as having a direct impact on the forms of knowing and being that are possible within contemporary societies. The thesis thus proposes that technological conditions exert a political effect on society through a mediation of the possibilities for knowing the world in ways that are consistent with types of computational knowledge. Furthermore, by identifying this convergence as a trend that is bound to historical moments in the development of science, technology and representation the thesis highlights the necessity to not only engage with contemporary conditions in their present state but to engage with the potential outcomes of current conditions on indeterminate forward looking timescales. As such thinking through the current trends of computationally constructed societies to an abstracted endpoint allows us to examine what elements of current technological practices have deeper future philosophical and political implications than may be possible if our examination is limited only to current and historical moments in this development. Examining development in this way, as a series of expanded trajectories rather than as a series of discrete steps at which point future directions are indeterminate, allows the thesis and the practice to explore trends that may otherwise appear insignificant in a survey of contemporary technology at any individual moment.

This complex relationship with time imparts on the thesis a particular trajectory that requires us[3] to move in varying directions through time both elapsed and imagined. In particular the thesis examines historical trends in measurement and abstract representation that are central to the scientific and technological developments leading up to the present and into the future. These trends are examined as practical and theoretical subject matters that dominate the construction of contemporary society. Doing so requires that we examine current and historical examples of computational practices in society. At the same time it is necessary to examine theories and practices of artistic and critical thought that engage with computational practices and that influence in varying degrees the contemporary thought on these subjects and the practices themselves. By proposing a convergence, part of a process that is not yet complete, and speculating towards the outcome of this process the thesis requires that we project our thoughts towards this future point. Doing so we must gather together the many strands that make up current technological practices and draw them into a common understanding – identifying that which is common amongst them and linking together parts that on the surface may appear separate. Finally, through the practice, the thesis

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[3] A note on voice: Throughout this thesis the first-person plural is used to describe the relationship between the author and the reader of the thesis as discursive partners. It is common in technical fields to use the first-person plural to describe the author of a thesis and the academy, as in the case "We have shown…". In this thesis, however, "we" is used based on the understanding in reading this text and the art practice of this PhD there exists a relationship between reader and author that produces knowledge that exists in the interaction of two subjects. As such, "we" is not used with the intention of claiming authority over the subjectivity of the reader or their agency in interpreting the thesis, rather it is used in an attempt to accept that the knowledge produced within this thesis exists as a relational process between subjects.

requires that we return to a point in the future that sits immediately after the present moment. In doing so we can examine the way in which this convergence continues such that it is possible to understand how the convergence towards universal[4] ontology of being impacts the possibilities for existence in the immediate future. This return to the immediate asks that we position ourselves as speculators in relation to practices as they exist now and how they impact on our subjective understanding of society. Through art practice the thesis asks that we become individual speculators as to the role of current technological practices in the construction of future societies. For the sake of clarity, it is necessary to briefly describe the sections of this thesis – in form and intention.

Having laid out the subject of this thesis and a trajectory for its examination it is important to give some guidance at the outset that will help the reading of this thesis at both a practical and theoretical level. Of primary importance in assisting this reading is to outline at the start the structure of this thesis as a whole. The thesis is composed in two primary parts, the first, which is contained within this text can be called the written part of the thesis, the second part, which is not contained within this text is the practice part of this thesis and consists of the exhibition of new art works that are created as part of the research of the thesis and which exist as part of its output. The two parts of this thesis are conceived of and structured as a whole despite the fact that each part may be encountered independently of the other and may still be capable of producing some understanding about of the issue with which the whole thesis is concerned. Before

[4] A note on terminology – The term 'universal' is used here to denote a common ontology, shared amongst individuals and machines. Whilst the term may have connotations of being determined from the universe, this is not the intended use. Rather universal here is used to denote an understanding that is the same amongst many, in this sense it relates to the older etymological route of the word in which universal relates to something that is whole or total and which occurs everywhere. Thus a 'universal ontology' describes the existence of a common understanding with which we relate to the world. This is best described by section 5.2.1 – The Universal Clock in which the understanding of time increasingly becomes structured around a that based on the clock.

detailing the relationship between these two parts of the thesis it is necessary also to mention a third complementary element. The third part of the thesis is intended as a solution to the difficulty evident in the relationship of practice-based research and the structure of academic research institutions. The written part of this document is available for continued access through the library or through electronic means. However, due to the nature of art practice in general, and the practice element of this thesis in particular, the practice part of the thesis cannot be available to be viewed outside of the context in which it is exhibited. As both parts of this thesis are of equal importance, and since the entire knowledge produced by this thesis cannot be determined from a single part of the thesis in isolation from the other it is necessary to find some way to make the practice accessible in an on-going way. In many projects of this type, the strategy that is employed is to allow access by means of photographic, audio, or audio-visual recording of the practice part of the thesis. This form of documentation is often accompanied by some description of the work or some reflective response to the work by the artist h/erself. In this case, however, for reasons that will become evident later in the thesis, in particular in *5 Unfolding and Entanglement* to do so would be to invalidate the function of art practice as a way of creating the sort of knowledge that this thesis deems necessary. In order to find a solution to this problem the thesis contains responses to the practice by two other artists. These responses do not form part of the main thesis of this work; rather they are subjective accounts of the encounter of these artists with the practice part of the thesis itself.

The thesis begins with *The Ontological Singularity*, a short fiction that adds to a shorter fiction by Borges. In it two imagined travellers recount their visits to a land of cartography. The Ontological Singularity is written, as Borges' text, in the form of a factual account from an imagined perspective, in this case a looking back from the imagined Ontological Singularity. The purpose of this fiction is to create the possibility of thinking about the imagined endpoint that is the Ontological Singularity in a way the separates it from the other purely theoretical aspects of the written material. In doing so, this fiction allows a discussion of the future point of current trends that does not collapse in to futurology or soothsaying but rather that places the future in a continuum that is already well underway. This portion of the thesis, however, is of course fiction in as much as it is impossible to discuss with any certainty that which has not yet occurred. However, it serves an important role in allowing the speculative endpoint of current technology to be named, to be thought of and to be examined so that we may better examine our position in a trajectory that may or may not end at that point.

Having speculated towards a possible outcome of current technological developments Chapter *2 Representation: A Critical Background* returns to more familiar ground. This chapter explores the history of the abstract representations that are central to a contemporary logic of computation. The chapter beings by exploring how different measurement technologies act as ways of encoding physical phenomena as abstract representations in such a way as that through the use of a known decoding operation some aspect of the encoded phenomenon can be communicated. It goes on to explore how these systems of abstract representation are central to the logic of computation that precedes modern day computing devices but on which all computation is based. The chapter continues to examine how based on such abstract representations algorithmic action exists as a process of making decisions in the abstract. Having explored these technologies and their theoretical underpinnings the chapter then examines various controversies in the assumptions on which they are based. In particular the chapter examines some of the work of feminist and Science and Technology Studies (STS) scholars that challenge the claims to objectivity and neutrality that are central to these measurement theories and to computational logic. In doing so the chapter explores the roles of subjectivity, power and context in the production of knowledge. As such this chapter opens up the first major tension between the global system of computation - a way of creating a universal ontological map for the world - and individual subjectivities and differing perspectives that occur within the grounds of that world being mapped. As such this chapter contributes a new understanding of computation that is based on practices of abstraction rather than on specific technologies.

3 On the Structure of Posthuman Technosocieties contains a review of recent and current critical and artistic works that attempt to elucidate in various ways the interrelation between computing technologies and contemporary society. In particular this section examines how other artists and theorists have focussed on different features of technology such as hardware, software and protocols in order to describe the fundamental features through which society is reconceived. The work of the artists and theorists is given equal position in order to demonstrate the relationship between artistic and theoretical approaches to enquiry and as a way of demonstrating the importance of these approaches in the creation of new knowledge. As such this chapter contributes an understanding of the value of arts practice in developing an understanding of technological development. In exposing how differing aspects of technological development tend to predominate within the field of critique the chapter highlights how these focuses tend towards technical and theoretical novelty and in many cases the investigations tend to recede in their prominence as their subject technologies reach the reduced levels of conscious visibility that equally accompany ubiquity or obsolescence. Finally, the chapter demonstrates that whilst these many theoretical and practical responses and inquiries are both useful and enlightening they generally fail to identify that aspect of technology that this thesis identifies as the dominant restructuring force in contemporary society – namely the reorganisation of society around abstract representations within the superstructure of a universal global ontology. As such this chapter demonstrates why the approach of this thesis on abstraction as the defining characteristic of computation constitutes a new and novel way for exploring a question that has so far failed to gather sufficient artistic and critical attention.

Having concluded a brief review of the theories that underpin the technologies of computation and having explored the work of other artists and theorists in examining this topic the thesis moves on to investigating in more detail the trend that is deemed central to this thesis. *4 The Convergence of Representation and Being* examines the increasing importance of abstract representation as a way of relating to the world. In doing so it follows a brief historical line that charts the development of universal clock time as an example of abstract representation before going on to highlight the current situation in which the generation of abstract representations can be seen occurring in ever new areas of existence. Through this examination the chapter goes on to show how, not only are abstract representations generated in ever new areas, but that these representations increasingly become the primary site through which we relate to the world. Having identified this trend the second part of the chapter proposes and examines mechanisms by which this trend occurs and reproduces itself. The discussion of this mechanism of reproduction is the point at which the trajectory of this project is brought up to the contemporary moment and after which we must return to the role of speculators with respect to future developments.

5 Unfolding and Entanglement demonstrates the role of art practice as a way of creating new and open-ended understandings of the current condition of contemporary technology and society. This chapter is not intended as a justification of arts practice within the context of an academic research thesis, rather it explores the way in which art practice is uniquely placed to address the issues raised within this thesis. In particular this section explores the way in which art practice creates new unstructured knowledge through affect. The chapter suggests how this affective knowledge can be productively utilised for understanding the ethics of engagement with contemporary systems of computation. It examines the role of practice through the concept of multiplicity, proposing that art produces new knowledge that is immanent to its perception and as such resistant to the representation within systems of computation. In so doing the chapter proposes how art can be used productively in response to the contemporary situations as part of a relational process rather than as a form of distant critique disconnected from a techno-political and ethical milieu.

Considering the form of the two main component parts of this thesis, practice and theory, it is necessary to discuss their relationship to the knowledge produced by this thesis in its entirety. Practice-based research in the arts is a relatively new approach to the creation of knowledge, however, it exists in a number of forms that carry important distinctions (Nimkulrat 2007). One form that is particularly dominant is the research *into* particular artistic practices and methodologies. This type of research includes the exploration of particular techniques in an attempt to uncover the limitations or opportunities contained within. This form of research tends to have a particular focus on self-reflection with respect to the artist/researcher's own practice and seeks to explore the tools that it employs. In contrast to this the other dominant form, with which this thesis is more broadly aligned, may be termed 'practice-led' (ibid) research. In this type of research, the practice takes the role of research methodology and is central to the creation of knowledge as the output of the research. In the case of this thesis, and as will be discussed in greater detail in *5 Unfolding and Entanglement* the knowledge that is produced by the practice section of this thesis can only be accessed through the interaction with the practice itself. As such the practice part of the research is central to that which constitutes the creation of new knowledge that is the aim of an academic research project. That is not to say, however, that the written part of this thesis does not also create new knowledge. The development of a new way to understand computation; the identification of certain trends across other areas of artistic and theoretical practice; the identification of an increasing tendency to relate to abstractions in contemporary society and the proposal of art practice as a certain form of knowledge making all exists as major contributions contained within the written part of the thesis. The written part thus consists a particular body of knowledge that is relevant to engaging with the practice element of the thesis as a form of academic research rather than as art that exists outside of an institutional context. In other words, the written part of the thesis contributes new knowledge within a traditional academic context whereas the practice produces the type of new knowledge that the thesis identifies as critical to understanding the implications of an increasingly computational society.

As can be seen through the description above, the trajectory of this thesis requires a series of alternate movements in time and through different modes of thinking – through theory, fiction and practice. Each moment brings with it a projection, or series of projections, into a set of imagined futures. The first of these projections, contained within *The Ontological Singularity,* exists as an endpoint back from which the present and immediate future can be drawn. The second is that which is encountered through the practice and projects into our immediate future. Whilst *The Ontological Singularity* projects to the endpoint of an imagined future it is the shorter of these two projections that is of greater importance. The theoretical projections exist as a model inasmuch as they provide an endpoint towards which other projections can be directed. The practice element of the thesis on the other hand requires a projection into the immediate and indeterminate future, anchored in each individual's subjective understanding of the world, as currently constructed and as subjectively experienced. As such the practice requests of us to project our own futures and to examine the endpoint and direction of current technological practices.

2 Representation: A Critical Background

2.1 Introduction

This thesis proposes that society is being restructured around the representational systems that form the basis of what we know commonly as computation. Before it is possible to examine this proposal and its impacts, it is unavoidable that we need to step backwards and take a view of representation and computation themselves. Doing so we will see that representation and computation are inexorably linked to each other. What we will also examine, however, is that computation – a term now so closely linked with the material of modern devices composed of semi-conductors, microchips and logic gates – rests upon an understanding of knowledge in scientific practice that dates back far beyond the plastic, metal and silicon composites of modern technology. What we will also see, however, is that the forms of knowledge on which computation are based admit and obscure politics and struggles for knowledge authority.

The first part of this survey, *Section 2.2 On Computational Thinking*, looks at the fundamental practices of representation within the body of techno-scientific practice. In particular *Section 2.2.1* examines how some material physical entity is abstracted into a system of measurement or encoding such that it can be processed, translated, further abstracted or manipulated *in absentia.* We will see briefly how the roots of this techno scientific paradigm were laid by the needs for coordination and trade of material and activities across vast distances such that recourse to the human senses and to human judgement was no longer possible. What will also be seen is that while measurement systems were proposed to solve these problems, they soon became seen as offering new and objective ways with which to relate to the world free from the biases and deficiencies of human senses and human minds. This survey examines the main paradigms of measurement theory and explores the ways in which the relationship between the abstract representation and the entity that it represents is proposed. Finally, *Section 2.2.2* will examine Abstraction Representation theory as a model for computation, and the manipulation of the abstract entities through algorithms will be explored. This will highlight how computation is a process of dealing with this abstracted information and of drawing conclusions, making predictions and carrying out actions based on these abstractions in a way that the results of the computation are assumed as equivalent to action in the material domain.

The second part of this survey *3.3 Partial Perspectives* acts as an examination and critique of the claims of the first. Through an examination of Science and Technology Studies (STS) – in particular the work of feminist and post-colonial STS scholars - the thesis examines the claims towards objectivity that underpin the techno-scientific paradigms of computation and the measurement practices that precede them. In *Section 3.3.1* what we will explore is how seemingly objective systems are underpinned by, and act to reinforce, struggles for power and authority that find their basis in the non-epistemic factors that surround their creation. What we see is that modelling the world through the abstracted structures of computation is both a constitutive and reactive process that is imbued with the politics of the world in which it is constructed. If measurement is the way to get the world *in* to systems of computation, then this section explores the way in which the world that is inside relates to that which is not.

2.2 On Computational Thinking

> *"All competent thinkers agree with Bacon that there can be no real knowledge except that which rests upon observed facts." - August Comte*

It is first necessary to try and define what is meant when talking about computing technologies. Technological development, as with development of any other element of human and non-human histories, is not easily broken into solid chunks that resist overlapping borders or that follow easily mapped and unilinear trajectories. In the same way, differing technological apparatus and practices surrounding or informed by technologies also tend towards a similar resistance to concrete and discrete categorisations. These histories and categories intertwine such that Babbage's 1833 analytical engine – often considered as the design for the first programmable computer (Manovich 2000, 21) – predates the invention of the Boolean Algebra that underpins all modern digital computers by almost twenty years. At the current end of computing development, biological computation and artificial intelligence blur the boundaries between computing machines and natural processes at the same time as computing infrastructures reshape the physical environment in which they exist – through the laying of cables or the transmission of electromagnetic signals.

It is necessary then to develop some form of categorisation and vocabulary that can inform this thesis and through which the computing technologies through which contemporary society is being transformed can be isolated. It is not without some small irony that we must first begin with a definition of terms and categories for computing technologies in order to ground this proposal, for as will become apparent later, the division of the world into strictly ordered categories is one of the features of computation that gives rise to this critique. For now, it is necessary to remain as oblivious to this irony – not to think in strict categorisations but to bear in mind that the definition of computing technologies with which we proceed is not enclosed by a sharp line but is a permeable category of those things and practices that appear to most closely resemble that which we will discuss.

A computing technology in the context of this thesis is a structure that organises the world through a system of abstract representations in order that manipulations, translations and transformations can be carried out on the representation as opposed to that which they represent. So for example, a calculator carries out operations on numbers, adding, subtracting and multiplying them without the need for or recourse to some physical quantity of objects as reference, or a digital camera represents intensities of light as numbers so that these can be decoded later as a digital image. To better define what this thesis describes as computing technologies it is necessary however to look back, beyond Babbage and Boole, toward some technologies, which might at first seem rudimentary with respect to modern computing technologies but which are essential to the way in which computers organise the world. These technologies are universal systems of measurement. Encoding phenomena for computer storage, manipulation and transfer requires that knowledge exists within a certain form so that it can exist within the binary systems of computer and network architectures[5]. It is possible to describe a number of criteria commensurate with encoding phenomena in this way; namely that they, or the knowledge produced by them, are measurable, definite and discrete.

Looking at these more closely; measurability is required as a way of translating external non-numerical phenomena into numerical values so that computational processes can understand them. Measuring is the way of getting the world *in* to computers. Another way of saying this is that knowledge must be representable, that it is possible for the computer to have some way to represent the phenomena within its internal data

[5] It is important here to note that there exist a series of developments in computing history that have not relied on the strict binary encodings that are associated with digital computation. Largely consigned to history, analogue computers used continuously variable physical phenomena to perform calculations, whilst in the developing present, quantum computation uses the quantum-mechanical phenomena of superposition and entanglement to hold multiple values of 1 and 0 in quantum states. Whilst this may appear to present a different model to computation, at present these technologies tend to operate digital (i.e. discrete) mathematical spaces to the input and output results. As such currently neither offer different *logic* of computation to that present in classical computation.

structure[6]. This means that a system is required to “sense” in some way the external phenomena in a machine-understandable way, but also that the phenomena must in some way be capable of being sensed. This can be, as in the previous example of the camera, an electrical transducer or some heterotic[7] form of data entry such as a person “liking” or retweeting something online. Definiteness in this respect relates to the ability to differentiate a phenomenon from a different phenomenon. It is the ability to say that if the measured value is x then it is not also y or z, where x is not equal to y or z within the abstract domain. In other words, definiteness relates to the ability to discriminate between phenomena in the physical domain. Finally, discreteness implies that the properties of the phenomena as encoded are contained fully within that which describes it, and as such are not contingent on the perspective of the measurer. It can be thought of as the ability to draw a boundary around that which is measured and to say where it begins and ends. For example, in the measurement of speed a discrete period of time must be selected over which to divide the distance travelled, or in the case of length a discrete resolution must exist with which to draw the start and end point of the measured distance. In other words, discreteness requires that all information can be ascertained relative to some objective external observer and datum. It is the ability to encapsulate a

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[6] In mathematics a metric is a function that defines the possibility of representation within a numeric system. In order for a metric to function, i.e. in order for the numeric system to represent the phenomena within a number system, a number of conditions must be satisfied. Namely; that for two distinct elements, there must be produced a discernable positive difference between them within the metric system; that for two distinct elements the difference between them must be the same within the metric system when measured in either direction, i.e. symmetric; and that for three distinct elements the difference between two elements can not be exceeded by taking an alternative path through another element.

[7] Heterotic here denotes an assemblage of human/machine action or activity where some part of the process action takes place is only possible through the mixture of human and non human action. This is distinct from strictly hybrid action in which the elements carried out by the human or machine actors are replaceable by either actor. For example a person using a numerical calculator to perform calculations would be a hybrid action, whereas the example in the text is an example of heterotic action – this definition is developed by Horsman in *Abstraction Representation Theory for Heterotic Physical Computing* (2015).

phenomenon as contained, define its boundaries such that they can be accounted for within the abstract domain.

In short, it can be proposed that computerisation of knowledge requires that a phenomenon's "qualities" are not reliant on the perspective of the holder, but that they can be universally understood and translated from one machine to the next provided both machines share the same representational ontology. Computation, thus, is a way of holding knowledge external to the individual such that it can be communicated and transferred without recourse to individual subjectivity. As representational systems, computing technologies are therefore heavily reliant on systems of measurement as a way of encoding the world, therefore it is first necessary to examine the underlying features of systems of measurement before we can return to computing technologies themselves.

2.2.1 Representational Systems – Abstracting the World

Many early technologies for measurement were inherently connected with the human body, and the senses[8]. The cubit, the length of the forearm from the elbow to the middle finger, varied from person to person. As a measure it also relied on an agreement based on sight that the measured object matched exactly the length of the measuring arm. Other systems such as the carat, based on the volume of carob seeds, both required, and helped to generate, consensus between any number of parties engaged in a transaction. As exchange of goods and knowledge across geographic areas increased rapidly in the latter part of the last millennium so too the drive towards standardised systems of measurement grew in such a way that one piece of value in one place could

[8] One set of early measuring technologies that were less concerned with the human body relate to measurements of the movement of the sun and of other astronomical phenomena. The relationship of these types of measurement and contemporary technologies is discussed in The Convergence of Representation and Being – in particular the way in which externally anchored measuring systems take the form of a network – linking common understandings between entities.

be exchanged for an equal value in another. Thus systems were required wherein the physical reality of the world could be abstracted in mutually agreed, unambivalent and universal ways. In this way transactions could be agreed remotely, without the need for confirmation by the human senses. Technology and measuring devices thus were required to become prosthetics for the human senses.

Modern systems of measurement[9] took as their defining moment the adoption of the metre at an international conference in Paris in the final year of the French Revolution, 1799. A universal system of measurement had been proposed by various scientists of The Enlightenment to enable scientific and commercial transfer across the borders of Europe. Little progress was made however, until the *Académie des Sciences* in Paris proposed the creation of a unit that represented one ten-millionth of the distance from the north pole to the equator. The metre, based on geometry at a planetary scale, was seen as being universal and objective, free from human ambivalence. It was to be, as leading Enlightenment and Revolutionary thinker, and member of the Académie, Condorcet declared, ‘for all people, for all time’ (Alder 2002, 1), and would, ‘ensure that in the future all citizens will be self-reliant in all those calculations which bear upon their own interests’ (Ibid. 136). This revolutionary break carried with it another implication for the idea of measurement, not only did it represent an exchangeable standard but a standard based on an abstraction of the world at a scale beyond which the human senses could have no recourse – not being able to confirm with the senses distance at such planetary scales. Universal measurement brought with it the promise of seeing the world without the distortion of human perspective, it was to be objective and neutral, a view of

[9] As of 2019 all nations with the exclusion of Liberia, Myanmar, Samoa and the United States of America use a mutually agreed set of abstractions for the physical world. The metric system is overseen by the *Comité International des Poids et Mesures*.

the world from above. Thus the metre and the units that followed became the first steps on the road to an understanding of the world through an agreed set of abstract representations. The understanding of the world through abstraction would become central to scientific and technological development up to the present day and gives rise to the logic of computation – the processing of abstract representations in place of that which they represent.

The growth of the systems of measurement in the period that followed this revolution, through modernity to the present day was a circular process of increased measuring and technological efficiency. The metre's own standard definition moved from the length of a physical platinum bar through interferometry to the distance travelled by light in a vacuum in 1 ⁄ 299,792,458th of a second, in each case carrying with it the errors and assumptions made by the initial surveyors Jean-Baptiste Delambre and Pierre Méchain[10]. The primary purpose of a measurement system is to communicate an understanding of the world in a numerical form such that we can carry out mathematical operations on these representations with the intention of understanding in greater depth the physical reality of that which is the basis of the representation. In the opening of their extensive study of measurement Krantz, Luce, Suppes and Tversky describe measurement thus, 'When we measure some attribute of a class of objects or events we associate numbers (or familiar mathematical entities, such as vectors) with the object such that the properties of the object are faithfully represented as numbers' (1971, 1). Central to the usefulness

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[10] Delambre and Méchain were charged with measuring the length of the earth's meridian from the pole to the equator. To do so they set out to measure from Dunkerque to Barcelona, both on the meridian through Paris in order to extrapolate the result. The value produced, which is the metre we use today, was a result of seven years of scientific, political and personal struggle for both men. Méchain, however, struggled most, he was tormented by inconsistent results from his measurements in Barcelona. These he hid from his colleague and the world for fear of damage to his reputation and the cause of science. He contemplated suicide for what he saw as his failures. Following the completion of the mission using his inconsistent data, Méchain convinced the *Academie* to allow him to extend the measurement beyond Barcelona. These new results he hoped would invalidate the mistakes that he had made. In this attempt he contracted yellow fever and died in Valencia in 1804.

of this concept are two assumptions, first that the units of measurement and operations upon them represent in some form amounts, degrees or intensities related to physical attributes, and changes upon them, within the scope of the system of measurement, and secondly that there is some justification for the correlation of the natural or observed system with numerical measurement systems (Domotor and Batitsky 2008, 129).

The basis and justification for these assumptions lies at the centre of the philosophy of measurement since the 1900s and a number of differing, if not always competing, perspectives attempt to formalise systems for these assumptions within measurement theories. The most dominant of these perspectives are the Representational Theory of Measurement (RTM), operationalist, conventionalist and realist approaches, whilst in recent years computing technologies have also brought forward the dominance of information-theoretic and model-based theories of measurement. It is worthwhile to give a brief description of these theories in order that we can bring forward an understanding of them into the discussion of how computing systems encode the world. A brief overview of the varying approaches is contained in the table below, it is noteworthy, however, that these different approaches do not necessarily represent diametrically opposed positions. They are best understood as highlighting different and complementary aspects of measurement and different focuses.

RTM which built on earlier work by Hölder, Helmhotz, Campbell, Russel and others (for an overview see Michell (1993) and Tal (2013)) was first formalised by Krantz *et al.* (1971) and is structured around the existence of a representational theorem which defines a measurement procedure as a homomorphism such that, ‘the existence of a homomorphism φ into a particular numerical relational structure, and a uniqueness theorem, which sets forth the permissible transformations φ → φ’ that also yield homomorphisms into the same numerical structure. A measurement procedure corresponds in the construction of a φ in the representation theorem' (Krantz et al. 1971, 12). In RTM then the representation and the operations on it are considered valid in as far as the transformations effected through the operations upon it (that is in the representational domain) yield representations that bear the same relation to the observed reality (in the physical domain). Critically, the requirement that the homomorphism φ within an empirical representational structure yields φ' within a numerical representational structure can only be proven with reference to empirical observation. For example, adding together of two measured lengths of 1m in the numerical domain yields a resultant length of 2m – taking two physical 1m rods, placing them end to end and measuring them to give 2m acts as empirical proof of the validity of the addition operation φ' in the representational domain. Primarily this empirical observation requires the solving of observed inequalities of properties required for the ordering of properties within a representational system – such as determining that the length of three such 1m rods is not equal to the length of the two 1m rods combined previously. Additionally, however, the determination of inequalities has an axiomatic and structural implication for RTM where properties such as the connectedness and transitivity of the measurement structure require not only solving of these inequalities but also the fixed nature of these observations for the axiomatic completeness of the representational system (Krantz et al. 1971, 14-17). In other words, the axiomatic basis for RTM and the validity of the operations carried out within the representational domain are proven with reference to empirical observation in the physical domain. The particular importance of RTM in understanding computation will be further discussed in *Section 2.2.2* where we will see how computation focuses on the carrying out of actions within the abstract domain.

Representational Theory of Measurement	Views measurement as the mapping of qualitative empirical relations to relations among numbers (or other mathematical entities).
Operationalists and conventionalists	Views measurement as a set of operations that shape the meaning and/or regulate the use of a quantity-term.
Realist	Views measurement as the estimation of mind-independent properties and/or relations.
Information-theoretic accounts	Views measurement as the gathering and interpretation of information about a system.
Model-based accounts	Views measurement as the coherent assignment of values to parameters in a theoretical and/or statistical model of a process.

Table 2.1 - Measurement Theories (Tal 2017)

The need for empirical observation for the development of its axioms has lead to criticisms of RTM as a measurement theory due to the limits of empirical determination of physical qualities (Domotor and Batitsky 2008) and that RTM is overly abstracted and fails to deal with the process by which measurement interacts with the measured world

(Michell 1999). These criticisms deal with the provability and practicality of RTM as a measurement paradigm. Conceptually RTM sees the measurement as an abstracted proxy for the real and the operations carried out within this domain can be seen as proxies for actions within the real-world domain. That the formalisation of RTM admits the requirement for empirical observation highlights in some way the contingent nature of measurement that will appear as a recurring tension in later sections. The basis of this can be seen in the first axiom of RTM wherein a weak ordered system must display the conditions of transitivity, i.e. if $a \preceq b$ and $b \preceq c$ then $a \preceq c$ (Krantz et al. 1971, 14). This property of transitivity is central to the property of definiteness discussed earlier – wherein an ordinal measuring system (as an ordinal number system) requires the values of an ordered system to be determined in such a way as can be determined from each other but also that these properties are fixed. Problems with this ordering arise when properties of inequalities give different results when viewed from the different subjective perspectives (as opposed to changes with respect to some numerical domain, e.g. time, which would not preclude the consistency of an ordering system). In other words, where a may be greater than b but also less than c dependent on in one valid real domain situation and at the same time a may be less than b but also less than c in another valid real situation – in which case two valid real perspectives or configurations are in disagreement when mapped into the ordering of the numerical domain. As such, RTM requires that for any given representational arrangement that order can be maintained between the real and numerical domains. A detailed example of this problematic position is as demonstrated in *Intransivity and Preference* (2004, 433-457) by Amos Tversky, one of Krantz co-authors in the definite text on RTM. It is, however, possible to demonstrate this with a simple example relating to preference for hot drinks. In this example assume preference for tea is denoted a, preference for coffee is denoted b, and preference for hot chocolate is denoted c. If when offered a choice between tea and coffee a person chooses coffee we can say that $a \preceq b$, if given a choice between coffee and hot chocolate the person chooses hot chocolate then we can say $b \preceq c$ from which it follows in an ordinal system displaying transitivity that the person prefers hot chocolate to tea, i.e. $a \preceq c$. What can be shown, however, in experiments such as Tversky's amongst many others is that when offered the choice between tea and hot chocolate the person may choose tea thus negating the transitivity of their preference. What this simple example describes is that in this case the preference cannot be mapped to an ordinal system within the numerical domain, the implications, however, increase greatly as we will see in later chapters and within this chapter when we consider the multitude of complex interrelations and subjectivities that are represented within the measured systems of computation.

Operationalism and conventionalism both also position measurement in the abstract and as such measurements are viewed as the result of operations carried out on the world itself, or through agreement (convention) about the way in which these operations are to be carried out[11]. Operationalism and conventionalism are closely related concepts – for operationalism, the resultant measurements are seen as stemming directly from the operation of measurement itself, in other words a measurement has a direct relation to the operation of its measurement but a secondary relation to the measured entity. This operationist perspective to measurement, stemming from an, at the time, burgeoning understanding of quantum physics and the role of apparatus in determining results, thus prefigures the position of model-based theories that the numerical domain may correlate

[11] It is worth noting that RTM also acknowledges the existence of conventions with respect to the choice of numerical system with which to represent some measured quantity (Krantz et al. 1971, 12), however, this choice is not central to the understanding of the measurement system itself. In the same way all other measurement systems include a conventionalist aspect that is required for the communication of their results.

to the physical reality but that it is not in itself the physical reality. Bridgman, who is central to the development of an operationist understanding of measurement, makes this point throughout *The Logic of Modern Physics* (1958) where he proposes that length measurements of different types, for example determined through the concatenation of rods and optically through the measurement of the travel of light should in fact be treated as distinct, highlighting the position that the numerical model has an intrinsic relation only to the measurement operation rather than the physical reality. Bridgman's operationism, however, proposed a problem for measurement inasmuch as it distanced measurement from an ultimate relation to the meaning of physical reality and thus presented difficulties for its ultimate usefulness as a method of communicating this reality (Chang 2009) and multiplied the meaning associated with each measurement by removing the possibility of their coordination. Despite this, we will see in *Section 2.3.1* that Bridgman's operationsim is echoed in the work of more recent STS accounts.

The difficulties presented by operationism and its distancing of meaning gave way to the pragmatic response of conventionalism. Here, the resulting measurements are also not defined with primary relation to the natural phenomena they express but in relation to an agreed set of principles by which they are produced. Critically, however, conventionalists take a pragmatic stance to the difference between measuring apparatus drawing their results together under the concept of what Carnap called 'correspondence rules' (1966, Ch. 24). In doing so conventialists dispensed with Bridgman's difficulties by relating the measurements produced by apparatuses to each other through the order produced in the numerical domain. Ellis describes this succinctly thus, 'If two sets of ordering relationships, logically independent of each other, always generate the same order under the same conditions, then it seems clear that we should suppose that they are ordering relationships for the same quantity' (1966, 34). Examples of this pragmatic basis for systems of measurement can be seen to extend to other difficulties in the relationship between the physical and measured world. In, amongst many examples, the description of a standard definition for boiling of water under standard atmospheric pressure and temperature, as discussed by Chang (2005), the inconclusiveness with which natural phenomena such as the boiling point of water occurs with relation to temperature is eliminated within the measurement system through the generation of conventions and consensus in measurement practices. In both operationalism and conventionalism then the world is known not through the assumption of an abstract representational transformation but rather that only through the operations that are carried out within an abstract system and as agreed by scientific convention can systems of practical usefulness be generated. In these views of measurement, the process of measuring and the knowledge produced become the primary focus of the measuring result. It is assumed however that the results of operations within the numerical domain have a practically similar relationship to results in the physical domain.

Chang's discussion of boiling point highlights the way in which small but real differences in observed phenomena are discounted or avoided in order to generate consistency in the measurement system. As Chang describes, 'gaps exist not because science is incapable of filling them, but because science needs to set aside many questions and facts in order to allow its current focus on the cutting edge of research' (2008, 239). It is possible to suggest that what the conventionalist approach highlights is that in the real-world production of scientific knowledge adherence to practices or conventions for the production of results are required to produce consistency within a measurement system. These conventions act as a network in as much as they coordinate diverse practices under common protocols in order to reproduce a scientific order and to allow scientists to "get on with" research practices, avoiding such difficulties as presented by Bridgman's approach. Importantly as we will show further in *Section 2.3.2* this coordination is central to the verification of scientific knowledge and thus critical to the ability to the legitimation of scientific practices.

The abstract and constructed implications of RTM, operationalist and conventionalist approaches gave rise to attempts at regrounding measurement philosophies within the real world. Realist interpretations of measurement such as those proposed by Trout and Michell position measurement as an approximating exercise of real-world quantities, properties that are intrinsic to the natural world regardless of the existence of a measuring system. In realist approaches increasing experimental accuracy is given as one reason for the existence of the real quantity regardless of the measuring operation, whilst on the other hand experimental error or inconsistency is seen as demonstrating the problems with assuming a homomorphic representational relation between the real world and the numerical system (Trout 1998, 56-57). Michell's perspective although somewhat different to Trout's also grounds the measurement result within the real and suggests that the measurement action is the attempt to discover the set of numerical ratios that exist between the real properties of things as categorised by their "strongly particularizing properties" (Michell 1994, 391), i.e. those properties that set them apart from other objects. This realist account in some respect exists as a complement of Bridgman's operationalism in that it suggests mathematical properties are intrinsic to the physical world and that measurement is the action of trying to discover these mathematical features, whilst at the same time the realist approach maintains some distance between real and numerical domains through the understanding of error, i.e. that the results within the numerical domain do not necessarily achieve totality in describing the mathematical characteristics of the real. Realist approaches then position themselves as approaching more closely the physical world itself, noting that operationalist and conventionalist approaches fail to sufficiently account for the physical reality of objects and reality of scientific practices while realist approaches tend to accept the validity of RTM (Tal 2017). Difficulties with realist theories arise when engaging with those phenomena that do not easily display strongly particularising properties or for which these particularising properties are not easily determined or agreed upon. For example, in the case of quantum properties that display alternate particularising properties or as in the example above when the determination of properties does not give rise to a consistent ordinal system in the numerical domain. As such realist approaches display limitations towards not easily empirically observed properties and thus question the validity of operations carried out within the numerical domain that produce new non-observable results.

In recent times information-theoretic and model-based theories of measurement have come to increased prevalence. This may in some part be due to the increased use of information technologies and statistical modelling methodologies across the sciences. Of primary interest here is how the method by which this type of approach acts as productive, rather than reactive, forces will be examined later. Information-theoretic accounts of measurement relate the measurement process or operation to the input-output relation in communication systems, in particular, the information-theoretic account regards the measured value as an output signal of the measuring process of the parameter to be measured, which exists as the input signal, the difference between the two values therefore being taken as the measurement system noise. This approach presupposes a number of important features with regards to the real parameter to be measured, primarily that the real-world value has some intelligible value that maps directly to the measuring system and therefore that system noise is an independent function that causes a distortion of the relation between input and output signals. The importance of these assumptions can be expanded from two statements of general information-theory such as proposed by Shannon below.

> *"The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic*

aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one selected from a set of possible messages" (1948, 379)

"In this case we may assume the received signal E to be a function of the transmitted signal S and a second variable, the noise N. E = f(S, N) The noise is considered to be a chance variable just as the message was above." (1948, 406)

An information-theoretic view of measurement then positions the primary concern of the measurement system as one of optimisation of a system in the apprehension of a predeployed model of the real-world parameter to be measured. The potential limitations of this approach are highlighted in some information-theoretic accounts, such as by Mari, who notes that the existence of a "measurand", a parameter which is to be mapped as input signal, cannot be taken for granted (1999, 185). As such information-theoretic theories refocus the question of measurement towards the measuring process itself but in doing so requires the acceptance of assumptions about the measured world – namely that it is composed of possible measurands. We will see later in *Chapter 4* that this informational view in which measurement is reconceived is accompanied by, in other fields of theory, a more general reconceiving of the world as a system of information flows, or indeed a system wholly composed of information.

Model-based theories of measurement, which have developed in recent years, in some respect follow conceptually from the more practically based theories developed in information-theoretic accounts. In model-based accounts the measurement process and result are split into two constituent parts, that is (i) a process that involves interaction between some object of interest, its environment, and some measuring apparatus and (ii) the deployment of some theoretical representational model that simplifies and connects the elements from the first process. With model-based accounts the difficulties presented by information theoretic accounts are avoided by the understanding that the measurand, the result of the interaction of the object of interest and the measuring apparatus or system, exists only within the model as opposed to being intensive to the object. In this case then, model-based accounts pay particular cognisance to measurement as a structured process and highlight the existence of predeployed assumptions, environmental factors and intersubjectivity within the creation of the measurement model. Model-based accounts therefore break from RTM accounts in so far as they do not assume the representational model is objective or intensive to the nature of the measured object (Frigerio, Giordani, and Mari 2010, 125). As such it is possible to suggest that model-based theories raise questions of politics that begin to undermine the possibility of a single totalising model for the world that is free from the power of a dominant perspective.

The existence of this number of varied models of measurement, their contentions and disagreements, give some indication of the inability to find a summarizing or overarching model for both the act of measurement and its results. Nevertheless, it is possible to note some consistencies across them and to understand the impact of these similarities in modelling the world – recalling Krantz et al.'s description from earlier 'When we measure some attribute of a class of objects or events we associate numbers (or familiar mathematical entities, such as vectors) with the object such that the properties of the object are faithfully represented as numbers' (1971, 1). In each understanding of measurement there is the requirement for an agreed system with which to relate the real to the measured result such that it allows the exchange of results in some translatable way. For RTM, realist, model-based and information-theroetic accounts this system is clearly defined as a representational system, be it assumed as intensive (stemming from the "true" nature of the physical reality) or contingent (stemming from the human production of scientific/measuring practices), or in the case of realist accounts an idealised but unattained approximation. In contrast the conventionalist and operationalist accounts the predeployed system is seen as a set of pragmatic tools which although have no assumed cardinal relationship to the real are used to inform our understanding and manipulation of the real via the numerical domain. The important commonality between these models is that in each there is the requirement to make objective or consistent some part of the modelling relationship between that which is measured – the physical world - and the result in order for the system to convey meaningful information. Each, however, admits its limitation in achieving a system that can describe totally that which it measures.

The problem of totality arises, it could be suggested, in the relationship of mathematics as a language for describing a world that rather than mathematical, is actually physical. In other words, the world exists as a fact outside of its construction in mathematical formulation. One way to think of this is through the existence of quantum phenomena wherein the wave-particle duality represents a schism between the understanding of behaviour of the physical world within two mathematical models. The existence of such a duality can be proposed, instead as nature acting duplicitously, as the inability of the model to sufficiently account for the complexity or actuality of the physical phenomena as it exists. In fact, the rigour and completeness of a mathematical system as a description gives rise to its inability to accurately account for the totality of other physical realities. As Chatalet suggests:

> *It is precisely this autonomy that was granted to the operators that allows them to be recognized as 'observables' in quantum mechanics. Paradoxical result: it is the motion itself of the amplifying abstraction of mathematics that governs their incarnation as physical beings: the more 'abstract' mathematics is, the better it works in application.* (1993, 5)

Whilst one may respond by suggesting that a sufficiently well developed mathematical language may be capable of accurately representing the totality of different and valid realities a further difficulty arises. As highlighted by Gödel in his famous incompleteness theorem, no consistent system of axioms is capable of proving all truths about the arithmetic of natural numbers, and as such that there will always be statements about natural numbers that will be unproveable within the system and following from which no system is capable of demonstrating its own completeness.

The striking implication of Gödel's work is the necessary separation between the numerical domain and the physical reality it describes. Despite speculative contentions such as Tegmark's Mathematical Universe Hypothesis (2008) (which as Tegmark concedes runs into significant difficulties with Gödel (ibid, 22)), the universe displays a completeness that precludes the totality of its description within mathematical structures as we know them and as such the representational structures of measurement will always consist an incomplete subset of the complexity of that which they represent. These structural problems for the possibility of a complete mathematical, computable and abstractly representable universe represent challenges to the total logical or philosophical consistency of a project of global or universal computation. What can be proposed as a result of Gödel's theorem, or for example through an understanding of the requirement for empirical proof in RTM, will be that any computational model of the world will always be incomplete in its description of the world, or in order to be complete will always display properties of inconsistency. That these challenges exist in the abstract and at the extreme reaches of such an understanding, however, does not give particular cause for relief, for as will be see in *Section 2.3* the task of measurement and data is also imbued with problems grounded in human inconsistency, incompleteness and in struggles for power and authority.

2.2.2 Computational Action - Decisions in the Abstract

If measurement represents the way of getting the world *in* to computable form it is also necessary to understand what happens next. In other words how computation *acts* on the abstracted representations to produce transformations, and critically how this action in the abstract domain relates to action in the physical domain. One particularly useful way to understand the relationship between measurement theories and computation is through the use of Abstraction/Representation (AR) Theory (C. Horsman et al. 2014) in computer science. AR Theory models a computational system by way of the relationship between abstract information and some physical entity to which it relates. AR theory's particular usefulness is that it models computation as a process that deals with the abstract representation of a physical domain entity – this approach can be seen as pragmatically acknowledging the existence of a representational relationship between the physical and abstract domains without explicitly needing to solve the nature of this relationship itself – e.g. whether the abstract is an approximation of the real or whether the abstraction is an independent structure built on the application of operations and conventions. In other words, AR theory acknowledges that for computation the primary concern is that the resulting relationship between abstract and physical entities is seen as being "good enough", i.e. that computation proceeds based on it effectiveness rather than conceptual rigour[12]. Whilst AR theory was first used to map the relationship between the abstract and physical information flows within what were explicitly intended as computing machines, the theory provides a conceptual basis for computation generally

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[12] The concept of "good enough" equality follows from the mathematical sign ≈ which denotes approximate equality. Approximate equality is used in physics, engineering and other applications of mathematics to denote something that can be taken broadly as being equal, but which cannot be mathematically proven to be exactly so. It is possible to suggest that the concept of modelling and representation of the physical world through mathematics is denoted by the engineering solution of "good enough" equivalence. What will be shown in *Section 2.3 Partial Perspectives* is that the concept of "good enough" equivalence is a subjective choice. Thus, it can be suggested that the validity of computation is reflective of the perspective from which this equivalence is determined.

by any physical system and later for heterotic combinations of physical and social assemblages (D. Horsman 2015), based on whether the processing of abstractions takes place. The way in which the relationship between abstract and real entities is formulated in AR theory is best demonstrated by the diagram show below (*Figure 2.1*).

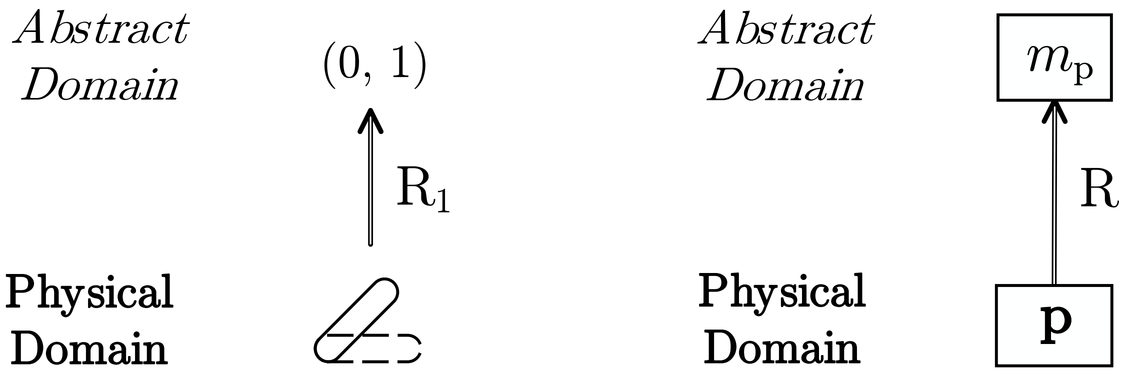

Figure 2.1 - Objects in the physical domain can be *represented* using objects in the abstract domain, such as (a) a switch with two settings represented as a bit through R_1, or (b) more generally as an object $\mathbf{p}$ represented as m_p through R.

As can be seen from the diagram (*Figure 2.1*) AR theory conceptualises the relationship between the physical and abstract entity by means of a modelling representational relation i.e. p *represents* some physical entity m_p *represents* the entity abstracted through the representational relationship R. This modelling relationship can be thought of as the same as that relationship that exists across the various measurement paradigms discussed above regardless of the particular paradigm's assumptions about the nature of this relationship with respect to reality. In this way computation operates on the basis that the system of measurement produces an acceptable equivalence between the measurand and the measurement – and as such proceeds agnostic to the difficulties highlighted in each of the measurement theories. AR theory makes explicit the link between this abstraction in computation and to the measurement and modelling of the sciences, 'This initial use of the representation relation in physics is fundamentally the process of modelling' (C. Horsman et al. 2014, 3). The key element in understanding AR theory, and indeed computation, however, is the relationship between the abstract transformed state m'_p and the abstract representation of the transformed physical state $m_{p'}$ (*Figure 2.2*). In this figure, as before, p *represents* some physical entity and m_p *represents* the entity abstracted through the representational relationship R. H(p) *represents* some action carried out on p in the physical domain to give p', and $C(m_p)$ *represents* some action carried out on m_p in the abstract domain to give m'_p, finally $m_{p'}$ *represents* the abstracted result of the physical transformed entity p'. For computation to be successful, it must be assumed that there is a "good enough" equivalence between the two states m'_p and m'_p.

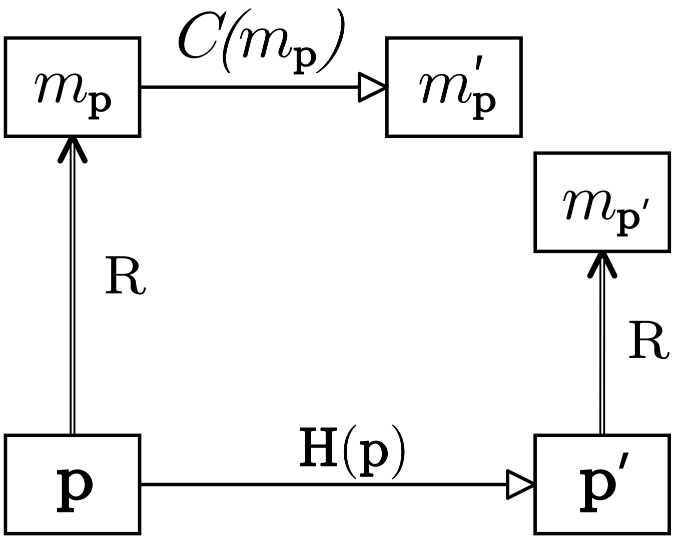

Figure 2.2 - AR Theory commuting diagram (C. Horsman et al. 2014).

The important assumption here is that if the abstracted transformation and the representation of the result of the physical transformation can be said to be sufficiently equivalent then it is possible to operate within the abstract domain and to draw adequate conclusions from these abstract operations. This statement is important in understanding the logic of computation in contemporary society as it gives the basis for decisions and actions carried out on data produced within the abstract domain and provides the justification for the algorithmic action of human, machine and heterotic computational action in contemporary society.

It is possible then, from our understanding of AR and measurement theory to see why we began this section with an expanded definition of computation. It is therefore useful to try and redefine computation here with a more robust definition that expands beyond the machines of semiconductors that we so closely associate with the word. We can define a computational system as a system that organises some set of entities through a system of abstract representations in order that manipulations, translations and transformations can be carried out upon the representations as opposed to that which they represent. For this definition to be useful, however, we must have an understanding of what the representational relationship is. And so, for the case of a network of computation (i.e. computation between entities) this system of abstract representation must be shared such that the encoding/decoding ontology of the systems is shared between the nodes of the network. In other words, both entities must understand the phenomenon in the same way. As can be seen above, computing technologies need some method by which to get external phenomena *in* to computing architectures. That is to say that computing technologies cannot generate an understanding of the external phenomena of the world without recourse to a series of sensors with which to gather data. However, in addition to this series of sensors computing technologies require a model with which to convert this “sensed” data into some form of representation such that secondary data or information can be generated from it. In some cases, representations can be produced with no assumed correlate in the world outside the machine, for example an iteration counter in the flow control of a piece of computer software relates only to the internal logic of the program. In other cases, which form the majority, the digitally encoded information relates to some real-world property, for example a location on the surface of the earth encoded as GPS coordinates, a person's heart rate measured through electrical activity in the skin or the colour of someone's eyes encoded through the sensors of a CMOS chip. In these cases then a computing system must employ and encoding with which to translate these external sensor values to "meaningful" information. For the representations to have meaning outside of the individual machine this encoding must be an agreed set of representational relations. Thus, it can be suggested that encoding of external phenomena within computation does not implicitly require the choice of measurement model be justified or that the foundational implications of the process of measurement be conceptually solved. Rather it is the sharing of these encoding/decoding relationships and decisions regarding the assumed equivalence between the abstracted and physical domains that define the possibility of computation.

It is possible to suggest that for the computational relationship between the abstract and the real, regardless of application, for these representations to have meaning to either human or computer users a predefined set of assumptions and standards and scales must be created – a fixed measurement system with which to relate the real to the abstract. In this way computation and measurement are reactive systems of capture, i.e. they relate to the world in a way that is defined before the event through, as we have seen, the applied models, conventions or assumed homomorphic relationships. The encoding relationship is a way of extracting from a real entity some relevant or functional characteristic. For example, the charge at a point on a circuit relative to the ground may determine a bit being one or zero, or a group of people may be arranged in a category based on their age or their economic means. In both cases, as in all cases of measurement, the process of capturing what is "relevant" to the representational system is a selective process. Some features will be discarded, intentionally or not, in order to allow the representation of the real thing to fit within the confines of the abstract system. In this way, representation can be seen as a subtraction of the irrelevant details from the physical entity. In mathematical language (following the lettering conventions from AR) we might say that $m_p \preccurlyeq P$, or that the representation of the entity is always less than the entity itself. What we can also say, is that for each entity represented there exist some other possible way to represent it, so for the voltage above the ground reference can be taken at some other point, or we can examine the voltage change or phase, for the group of people we could look at their weight, how likely they are to buy different brands of soap on days they fight with their neighbours. This point is neatly summed up in the discussion of AR theory where Horsman notes, ‘It is important to notice that the representation of any given system is not unique: for example, a rubidium atom can be represented as a quantum bit (qubit), or as the solution to a master equation, or as a multi-level system with many orbitals’ (C. Horsman et al. 2014, 3). It is possible then to develop a definition for representation to accompany our definition for computing. As such, representation is a predefined or understood convention used to translate some aspect of an entity into an abstract space. We can develop this in mathematical language by saying representation is a function carried out on some real entity E to create a representation R such that $f(E) = R$ and $R \preccurlyeq E$ where $f = \Sigma f_1 + f_2 + \ldots + f_n$ and $f_1 \ldots f_n$ are the elements of technological, political, epistemic, ethical, etc. frameworks that mediate the perception of the system in which the representation function takes place. What it is therefore possible to suggest is that there are an unknown number of other valid representations R of any given entity that can be considered consistent within their representational scheme. Recalling Gödel, however, what can be said is that it is not possible to produce a representational system R that is equal to E and that such a system would be inconsistent, i.e. it would contain statements that contradict each other.

This understanding of representations gives rise to some important questions; firstly given that the models with which we relate to the world influence the way in which we think about it and given computing technologies rely on a representations that are predetermined, i.e. they act *a posteriori* to existing systems of knowledge, how do these representations influence our way of being and living in the world? And how does the increasing prevalence of these systems of knowing affect the possibilities for the generation of new ways of knowing? What we will also see later in this thesis, in particular in *Chapter 4* is that the information theory of computer networks – in particular as described by Shannon - in order to maintain a complete and communicable representational system across the network not only must the representational system be shared but we must also conceive of new phenomena within the framework of pre-existing representations – a requirement that gives rise to profound philosophical and political implications at individual and societal levels*.* *Section 2.3* explores the frameworks that mediate how these abstract representations are constructed. However, before proceeding to this it is necessary to explore one more aspect of computational systems that is relevant to our enquiry.

Computing technologies then are particular forms of machine that work with a form of mathematical logic, the transformations and data structures of which they are comprised rely on decisions based on mapping the world into mathematical structures. It is this feature then that we will use to describe computing technologies throughout this thesis; that is systems that relate to the world through a system of abstraction, representation and manipulation. As we will see, this definition broadly encompasses what are generally known as computing machines. However, beyond this it also encompasses a range of practices that exist outside of the material substrates of electronics such that it becomes a way of looking at computing as a political and social practice. This way of acting on abstract entities, i.e. carrying out transformation in the abstract domain, can be thought of as algorithmic action. The term algorithm is generally given to describe a set of repeated steps that can be carried out to perform some particular function, often a compound of many steps, for example sorting a list of pupils by age, or employees by salary, or determining credit worthiness by address of applicant. In computer science, algorithms are the entities that "do" the computation, taking inputted information and producing some output – making decisions based on the abstract entities of data. It is possible, however, to think of the simplest operations as algorithms and of all other more complex operations to be combinations of various simpler steps. This approach, which generally stems from the seminal work of Church (1936) and Turing[13] (1936), sees an algorithm as that which can perform any calculable procedure (Gurevich 2000, 1)(Minsky 1967, 108). Taking, for example, two numbers a and b in the abstract domain representing the length of two rods, the length of the two rods joined at their ends can be determined using the function $c = f(a,b) = a+b$. Here the inputs a and b produce and output c through the simple single step algorithm that adds the value of a and b. As we have seen from AR theory, we can think of this as computation if we accept that the abstract value c is a sufficiently valid representation of the length of the two concatenated rods.

We can think then of an algorithm as any process that acts in the abstract domain. Using this expanded definition, it is possible to expand beyond the electronic substrates of computing machines and consider wider social and political practices as being algorithmic if they act on or with abstract representations as part of their decision making processes. Thinking in this way we can consider heterotic assemblages of human and machine activity to be considered algorithmic when the affordances or processes of

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[13] Turing and Church's parallel work on the *entscheidungsproblem* – David Hilbert's 1928 decision problem – relates to, and is built upon, the earlier work of Gödel. What both showed was that there exists a set of problems for which solutions are incomputable within the field of natural numbers.

abstract representational machines combine with human action in order to create new hybrid behaviours. For example, the self-censorship and curation of a user own activities on social networking sites in order to maximise visibility to others, or the direction of academic activities in order to maximise university ranking scores can be seen as algorithmic within this expanded scope. What we will see in *Chapter 4* is that as this logic of computation expands throughout society, the boundary between that which exists in the abstract domain and that, which exists outside of it, becomes increasingly porous.

If the algorithm is the transformational element of the expanded logic of computation it is necessary to think about the relationship between this abstract action and action in the physical domain. In the model proposed by AR theory the transformations in the abstract domain are related to correlate physical transformations through the assumed equivalency of their outputs. Algorithmic action however proceeds through a set of well-defined and repeatable actions that map abstract entities of known types into other entities of known types. As such, algorithmic actions not only require that the entities display a formal regularity but additionally they can only produce outputs of the predetermined formal types. As such algorithmic action is limited in relating the world through the set of agreed representational encoding ontologies within a measurement paradigm, but furthermore they are limited by the formal constraints of computational systems. In other words, we can suggest that algorithmic action is limited to produce actions that are framed within the terms that their formal systems allow.

2.3 Partial Perspectives

"For the master's tools will never dismantle the master's house" – Audre Lorde

Computation can be thought of as an attempt to employ an objective model of the world such that decisions can be made based on this model. The creation of a universal abstract model of the world that is fundamental in what we can call computation rests upon a number of assumptions about the nature of knowledge, measurement and objectivity. These assumptions have as their basis the development of the modern scientific method from The Enlightenment through to the present day. It is of course incorrect to suggest that any philosophical proposal or theory has ever enjoyed an easy existence with respect to its validity. Even within the surroundings of companion theories and within friendly institutional environments, proposals undergo rigorous examination as to the basis of their claims. The requirements of demonstration and validation for such claims in front of academic peers and the wider community in part gave rise to the development of the universal systems of measurement discussed in *Section 2.2.1.* as a way of producing knowledge in such a way that its validation could be shared and confirmed independent of the producer. However, despite, or perhaps because of this, what we will see is that the production of abstract knowledge has been inseparable from the politics of power and authority.

2.3.1 Objectivity and the Construction of Knowledge

Central to the historical development of modern scientific knowledge and methods are claims towards the objectivity of knowledge that could be determined through empirical and positivist research and experimental methods. In other words, knowledge that could be repeatedly and consistently generated within the systems of scientific measurement was seen as being generated free from the subjectivity of its creator. As with a society mapped through computation these methods were proposed to create a universal model of existence through primarily mathematical structures. In this way it was thought that hypotheses and predictions about the totality of the universe's functioning could be developed. Through this a complete and unambivalent understanding of the world around us and our place within it, would be attained. The development of this universal and objective science required that the claims and theories that formed the model of the world would be open to verification and falsification within the body of scientific knowledge and within the academic community. Thus a universal and objective model would have as its source the true nature of being, developed through accepted methods of enquiry and refined through falsification of defective and incoherent thought.

It is not necessary to demonstrate the dominance of this ideal of objectivity throughout the work of Enlightenment scientists and philosophers such as Bacon, Descartes, Kant, Hume and Newton for much scholarly work, such as that of Daston and Galison (2007), describes this in far greater detail than is possible here. Across all of this work it is possible to suggest that the true nature of the universe was to be found by the removal of the individual from the observation. As Daston and Galison observe, 'To be objective is to aspire to knowledge that bears no trace of the knower — knowledge unmarked by prejudice or skill, fantasy or judgment, wishing or striving. Objectivity is blind sight, seeing without inference, interpretation, or intelligence' (ibid.). Objectivity then was to offer the removal of the observer, a significantly rigorous model would remove human error and so too then the removal of politics and inconsistency.

These perceived ideals of openness and transparency flowed through much of the thought of the Enlightenment and this spirit can be seen in many of the periods' most important works such as Comte's *Religion of Humanity*, Descartes' *Meditations on First Philosophy*, Bacon's *New Atlantis,* Condorcet's *Sketch for a Historical Picture of the Progress of the Human Spirit* and Mill's *On Liberty*[14]. Of these texts, perhaps Mill's most

[14] It is worth noting that whilst many of the texts of this period, such as those highlighted in this section, do not stand up to the political and social standards of the present day it must be

easily highlights one of the flaws that we will see as becoming ever more evident as the study of science developed towards the present day (although the fact that the list of names comprises completely of a wealthy class of male individuals from a small geographical region may in fact be enough to hint us in that direction) where he notes that access to these ideals apply to a select group and not to "barbarians" for whom those non-barbarians may decide what is best (Mill 2001, 14). Despite the ideals of openness and equality, the community and their methods by which truth could be validated represented only a small subsection of the society, and one that represented the most powerful both globally and within their community – a point which we will see in more detail in the discussion of knowledge legitimation in *Section 2.3.2*.

Since the latter part of the twentieth century this question of *for* and *by whom* scientific "objectivity" was created has raised important questions about the nature of scientific enquiry (Harding 1980, 1993, 2011; Barad 1996, 2002; Haraway 1988; Latour 1987; Said 1978; Weiler 2009; Hacking 1982, 1999; Polanco 2006;). The proposal of subjectivity and situatedness in the production of scientific knowledge challenges the very possibility of a universal objective model with which the world can be known – proposing instead that many different competing understandings of the world are in existence at any one time. In particular feminist and post-colonial studies have highlighted important expressions and expressers of power in the creation of scientific knowledge. Meanwhile Science and Technology Studies (STS) more broadly has highlighted the contingent, contextual and subjective nature of scientific research. What these STS fields have

remembered that the social context in which they were made is inseparable from the content of their ideas. In fact, it is all the more remarkable that texts such as Condorcet's "Sketch" broadly stands up to current unachieved ideals for equality regardless of race, gender and class. As such, and as with all historical moments it is necessary to remember that some of the positions that may now seem obsolete or in fact regressive in today's context may have contributed greatly to just such a context in ways that can be perceived as both positive and negative depending on the perspective of the observer.

shown is that while scientific truth can be produced, claims towards the universality of such truth requires careful investigation. It is worthwhile to examine briefly some of the work of these fields, not to carry out a full survey or in depth analysis of the state of these debates, but in order to see how the lessons learned and controversies that exist in these areas can provide some context to the understanding the universal systems of representation that increasingly underpin the computational societies we inhabit.

At the centre of the challenging perspectives that STS brings to the examination of scientific enquiry is the interrelation between the epistemic and non-epistemic factors in the production of scientific knowledge. In other words, what portion of the knowledge is inherent to the subject of the study itself (the epistemic portion) and what portion of the knowledge stems from other contextual factors (the non-epistemic portion)? Whilst the proposal for an objective science – a blind vision – suggests the inclusion of only epistemic factors, that is factors that are inherent and immanent to the knowledge itself, the validity of this position has been increasingly challenged throughout the late twentieth century to the present day. In particular the structure of scientific institutions, the production and maintenance of disciplinary authority and the production of research methodologies and results have come under scrutiny, with awareness that non-epistemic factors play crucial parts in each.

It seems natural to begin this enquiry within the domain of STS, a field that deals primarily with the non-epistemic factors that surround the production of scientific knowledge and that also encompass many of the perspectives from the related fields of feminist and post-colonial studies. For the field of STS, as with all the histories we have seen, it is hard to define a particular beginning. Many of the Enlightenment texts on scientific method were themselves documents of the procedures of producing knowledge. STS can be thought of as a meta-epistemology, a study of study – concerned not with the knowledge that is produced but the way in which it is produced.

The “big-bang” moment for STS as a modern discipline, however, is most commonly traced to the work of Thomas Kuhn, and in particular to the publication of *The Structure of Scientific Revolutions*. Kuhn proposed that rather than through a linear and progressive movement towards the discovery of some true nature of reality that science progresses through the movement of paradigmatic shifts. These, he proposed reflect socially, historically and theoretically incoherent states to those that precede them but that, ‘preserve a great deal of the most concrete parts of past achievement and they always permit additional concrete problem-solutions besides’ (Kuhn 1996, 168). Since Kuhn’s work the field of Science Studies has focussed on the way scientific paradigms take hold or, through scientific revolutions, become replaced, and also on the ways in which the production of scientific knowledge represents the milieu of these paradigms.

Science, Kuhn’s work proposes, is produced in a teleological manner and as a result of the historical and surrounding meta-science. This point is picked up by Žižek when he notes that within the hermeneutical frame that surrounds knowledge production, ’there is no view that is not framed by a historically determined horizon of “preunderstanding”’ (2001, 18). This preunderstanding, or the hermeneutical and social frame from which it may be derived is also that which Hegel (1977) and Marx (Marx and Engels 1998) describe as a non-epistemic function of knowledge formation in the case of master/slave or unequal power relations. That is to say, that knowledge is a hybridisation of the epistemic elements and the existing social structures that surround it. This idea that knowledge production plays out and regenerates existing power relations was further developed by Hartsock (1983) and others into modern feminist standpoint theory, which we will see later in this chapter. The publishing of Kuhn’s work itself is an interesting example of his own ideas of paradigmatic change. Having initially been published in the

International Encyclopedia of Unified Science, a publication of the Vienna Circle[15] designed to develop and promote a positivist and unified scientific understanding of reality, Kuhn's work came to highlight the non-epistemic underpinnings of such a proposal. The controversy that surrounded its publication was in many ways a result of the tension that existed between ideas of objective and subjective knowledge and highlighted the resistance to the development of new paradigms.

The central claim that there exists a standpoint that influences the creation of scientific knowledge is that knowledge is socially constructed rather than being the discovery of a universal and human independent *a priori* phenomenon. That is to say in the creation of such knowledge there are some more or less present hermeneutical factors that influence the knowledge that is produced. It is important to state here that this claim does not deny the existence of human independent phenomena but rather that our understanding of them is inherently human. For this reason, it is useful for the moment to proceed with the term "social constructivism" to describe the position that scientific knowledge has in its formation some non-epistemic foundations and influencing factors. This claim and its implications form one of the most contentious topics in the field of science studies, and in science itself. The contentiousness around this issue is perhaps best demonstrated by the "Science Wars" episode (Sokal 1998) (Fuller 1999) during which mathematician Alan Sokal attempted to discredit the validity of constructivist theories by highlighting a perceived lack of academic rigour applied to some of the field's academic texts[16]. It is worthwhile to examine some of the issues at stake here before

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[15] The Vienna Circle of Logical Empiricism was an influential group of scientist and philosophers who met originally in Vienna in 1924. The circle forwarded a position of logical positivism and attempted to produce a "unification of the sciences". Amongst their outputs are included the hugely influential *International Encyclopedia of Unified Science.* Amongst their membership and associates were Moritz Schlick, Rudolf Carnap, Kurt Gödel, Ludwig Wittgenstein and Karl Popper and John Dewey.

[16] Science Wars, as it came to be known, was a series of academic exchanges that came to be most closely associated with the publication by Alan Sokal of *Transgressing the Boundaries: Towards a Transformative Hermeneutics of Quantum Gravity* (1996) in the journal *Social Text*.

proceeding further, although it is noteworthy that as an issue the division between constructivists and realists is still hotly contested both academically and politically. A single unified solution (such as desired by the Vienna Circle) may not be forthcoming – or necessarily desirable.

One of the main arguments that is routinely proposed against social construction and for scientific realism and objectivity is the existence of fundamental phenomena such as gravity or fundamental particles such as quarks that exist in a universally confirmable manner. This position is neatly summed up by Dawkins who says, ‘Show me a cultural relativist at 30,000 feet and I will show you a hypocrite” (quoted in Bailey 2001). Dawkins' remark suggests social construction, or social constructivists, denies the existence of such phenomena or proposes that the phenomena are entirely social constructs. Generally, however, social constructivism is focussed instead on the way in which scientific knowledge represents such phenomena. In other words, social constructivist positions suggest that whilst phenomena exist and can be observed, the particulars of how the phenomena are represented and how they relate to the fields in which they exist, demonstrate elements of non-epistemic and heuristic knowledge. In fact Dawkins' choice of gravity offers a useful example. The understanding of gravity has changed from Aristotle – in which each entity had its own natural place within the geocentric universe, through Galileo and Newton – constant acceleration between objects of mass, to Einstein's general relativity and into quantum mechanics – bending of time/space around objects of mass. With each of these changes there is no suggestion that the fundamental

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On the day of its publication by *Social Text* Sokal revealed in the magazine *Lingua Franca* that the article had been a hoax and was, ‘a pastiche of left-wing cant, fawning references, grandiose quotations, and outright nonsense ... structured around the silliest quotations [by postmodernist academics] he could find about mathematics and physics' (Sokal 1996a). The publication of Sokal's articles and the following responses by editors and perceived targets of the hoax such as Latour and Derrida became seen as typical of a contest between what were perceived as constructivists on one side and scientific realists on the other.

forces of nature reorganise themselves, instead the construction of that which is termed as "gravity" is fundamentally changed. It is possible to think of this reorganisation of the conceptual language for the description of the physical concept in the terms discussed earlier in *Section 2.2.1*. Namely that mathematical or conceptual language acts as a model that describes the physical world but which is limited in its ability to do so completely.

This point is picked upon by Hacking, who describes it with reference to Putnam's referential model of meaning. Hacking says that whilst Aristotle and Einstein may have vastly different conceptions of what gravity is and how it works "gravity" the subject remains constant and the theory through which it is defined is what is changed (1982, 157-159). In this way Hacking draws a distinction between the phenomenon itself and the models that describe the phenomenon in the abstract. The argument against social construction, however, would suggest that each of these revisions is the shedding of defective knowledge and a closer approach to a real understanding of gravity's "true nature". Regardless, it can be suggested that the current state of knowledge thus reflects the specific frame in which it is produced whether this frame is limited either by a standpoint as well as by the technical, conceptual and experimental limitations of current understanding.

"True nature" in the case of gravity or in any other case is determined as that which fits into, and is consistent with, the accepted bodies of theory of which gravity forms an essential part. In the case of gravity then, what is at stake with construction is not at stake at 30,000 feet, except maybe for Icarus, rather it is at stake in laboratories, research centres, academic bodies and experimental apparatus (such as LIGO and Virgo that are designed to detect the gravitational waves[17] proposed by Einstein and central to his understanding of the phenomenon). The stake of constructivism in experiments such as these, or in the description of the fundamental and unobservable aspects of physics, is in the deployment and revision of a model through experimental practice. The way in which these models are adapted to the experimental results, it can be suggested, are not wholly determined by the existing external observed phenomena. So in the example of gravitational waves, the experimental apparatus are constructed consistently with the model proposed by Einstein, whereas if an alternate theory existed that was equally consistent with pre-existing experimental results an alternate apparatus could equally detect results consistent with this model. The importance of this distinction is that it does not suggest that, for example, gravitational waves do not exist, but rather that the theory of gravitational waves is one version of the theory that can connect the dots of previous experimental observation with new observations. Equally, other models are possible that can encompass all previous experimental data and produce an alternate theory that is equally consistent. The difference between these alternate theories is, constructivism argues, determined by non-epistemic factors. Following on from Hacking, however, each alternate model can be seen as distinct from the phenomenon itself.

This condition, wherein the pre-existing body of theory is embedded within a proposal for new theories can be seen as an example of the Duhem-Quine thesis. The Duhem-Quine thesis proposes that no hypothesis can predict future outcomes without reference to a set of background hypotheses that must also be taken as correct, or accordingly that no hypothesis can be proven without also proving the set of hypotheses on which it is

[17] LIGO is the Laser Interferometer Gravitational-Wave Observatory in the United States, whereas VIRGO based in Italy is a European Gravitational-Wave interferometer. They jointly publish their results and have reported the detection of gravitational waves since February 11th, 2016.

predicated. Duhem-Quine does not imply that the direction of future knowledge is not predetermined from pre-existing empirical data but rather that the existing body of theory represents a way of explaining the current state with reference to the existing body of knowledge. Pickering examines this condition with recourse to the discovery/conceptualisation of the quark in *Constructing Quarks.* He proposes that the quark was one of many possible alternate solutions to the construction of matter and that differing alternate models could have come into existence that would differently shape the future direction of scientific work after the quark (1984). Social construction then does not imply the non-existence of phenomena, nor does it imply that a realist conception of science is impossible, rather it implies that scientific knowledge is a socially subjective frame through which the world is known. Thus, a Kuhnian paradigm is a subset of knowledge based on the frame through which it is constructed.

Having briefly addressed, perhaps, the main debates that surround ideas of scientific construction and the complementary realist interpretations of science, it is now worthwhile examining a little bit more closely some of the theoretical positions that make up constructivist arguments with which we will proceed. In doing so we can examine the way scientific objectivity functions, or does not function, as a form of partial perspective on the nature of reality. Kuhn proposes that objectivity exists only within the constraints of a specific frame, and that these frames while having their own objectivity are incommensurable with alternate frames (1996). This suggests that whilst each theoretical framework may be internally and empirically consistent, and consistent with the preceding body of empirical and theoretical work these frames cannot describe the conditions presented in alternate frames in a theoretically or experimentally consistent way. The idea of multiple and alternate objectivities, that is multiple internally consistent frames, is explored in particular by feminist theorists, most notably by Haraway. Haraway proposes that objectivity is only possible with reference to and acknowledgement of the standpoint from which it is viewed as opposed to some supposed transcendent and disinterested position, this she calls “Situated Knowledge”.

> *“So, not so perversely, objectivity turns out to be about particular and specific embodiment and definitely not about the false vision promising transcendence of all limits and responsibility. The moral is simple: only partial perspective promises objective vision.”* (1988, 582-3)

Harding takes up this proposal in her discussion of what she terms “Strong Objectivity” where she suggests that a reflexivity and admission of a researcher’s standpoint, as opposed to a proposal to disinterested neutrality, increases the objectivity of the research. Further to this, she suggests that marginalised groups have a potential for increased objectivity through an awareness of the marginalising and striating framework as well as a vision of the epistemic concern (1993). In other words, Harding’s and Haraway’s proposals suggest that a lack of awareness of the standpoint or the non-epistemic factors in knowledge production act to limit the objective potential of knowledge creation, and that only through acknowledgement of these factors can knowledge attempt to regain some objectivity. Extending from Haraway and Harding’s requirements for reflexivity and standpoint awareness Barad brings these concerns back to the world of particle physics to propose a system that accepts both the need for, and understanding of, the material world as it functions but that takes account of the variety and difference of local knowledges. Barad starts with Bohr’s statement on the taken “as-is” nature of assumptions in the production of experimental results, a statement that closely aligns with the Duhem-Quine thesis.

> *‘Often the development of physics has taught us that a consistent application of even the most elementary concepts indispensable for the description of daily experience, is based on assumptions initially unnoticed, the explicit consideration*

of which is, however, essential if we wish to obtain a classification of more extended domains of experience as clear and as free from arbitrariness as possible....' (1937, 289-90)

She goes on to note that in discussing quantum mechanics Bohr states that in the process of observation, the object of measurement cannot be separated from either the experimental apparatus of observation or from the conceptual model in which this apparatus is produced. This she notes implies that in order to make a particular measurement, the observer must create the separation between observed and observer that is specific to the frame of that individual measuring procedure.

'This particular constructed cut resolves the ambiguities only for a given context; it marks off and is part of a particular instance of wholeness, that is, a particular phenomenon.' (1996, 171)

As such it seems that even for scientific apparatus the production of knowledge can be seen as resulting from the interaction of a sensing subject and a phenomenon. Barad develops from this her theory of "Agential Realism" in which she proposes that knowledge is embodied in local experience and produced in equality by the material and cultural (ibid, 179). What can be seen also in Barad's notion is that in the act of measurement is not only the drawing of a line around that which is measured, but also drawing a line around oneself as observer.

It is thus possible to suggest that the requirements of computation for a consistent model of the world, i.e. one that displays the properties of consistence even when viewed from the multitude of perspectives that exist, may not only be technically limited by the possibilities of formal systems but may not be reflective of the complex and multiple nature of existence. What the discussion of partial perspectives and objectivity suggests is that a model that attempts to enclose the world in a single truth may in fact obscure the complex reality of many contradicting truths that exist.

2.3.2 Knowledge Authority – Between Objectivity and Politics

If we accept that non-epistemic factors can play a role in the production of scientific knowledge, then it is also necessary to examine what the implications of this role are. Doing so we will see how knowledge and knowledge authority act as political functions and create political affects. The political function of knowledge is more specifically highlighted within the STS subdomains of feminist epistemologies and postcolonial studies. Weiler highlights that much of the contemporary discourses around knowledge fail to address these concerns where he notes that, '[knowledge discourse] does not take a sufficiently critical view of what "knowledge" means, and of the fundamental changes that the concept of knowledge has undergone in the course of the 20th century', and, 'it fails to address the political conditions and consequences of the production and use of knowledge – in other words, it is largely oblivious to the politics of knowledge' (2009, 1). This failure to address the politics of knowledge it can be suggested is grounded in the perceived neutral, or disinterested, stance ascribed to scientific objectivity. However, what feminist and post-colonial science studies have attempted to show is that this neutrality often exists only with respect to those groups with whom knowledge authority rests rather than with such marginalised groups mentioned by Harding above.

One particularly useful framework, or series of accounts, that deal with the interrelation of knowledge and power is the work of Michel Foucault. Foucault deals particularly with the human sciences, which he notes as having an epistemic profile that is significantly less embedded in deeply granted constructions and thus allows for an easier critique (1980, 109). One such area of this focus falls upon the psychiatric and penal structures in Western Europe and more particularly in France. Throughout his accounts he discusses how scientific knowledge is "applied" as a form of power for the control or repression of an individual. It is, however, his discussion of monitoring as a role in control that is of most interest to this thesis. In particular, in his discussion of Jeremy Bentham's Panopticon, an institution designed for the control or surveillance equally of students, children, prisoners or patients Foucault notes that, 'there was a central observation-point which served as the focus of the exercise of power and, simultaneously, for the registration of knowledge' (1980, 148). What is of interest here is how Foucault inextricably links the bearer of vision to the seat of power. What Foucault suggests is that the power of knowledge is inherently vested in those who produce it. This power inherent in the vision that Foucault identifies within the human sciences Haraway also identifies in the natural sciences. Haraway notes that the "unmarked" vision's objectivity that is implied in scientific objectivity is the vision of the white male through which western science was developed. This vision that marks out the bearer from the viewed sets up a dichotomous binary where the unmarked objective view is the embedded natural and the viewpoint of the viewed is that of other. This dichotomy of viewer and viewed is reflected in the act of measurement, the measured subject being ontologically separated from the socio-technical apparatus by which it is measured. It may be suggested the effect here is increased as the technical apparatus acts to obstruct its social construction, increasing claims towards the neutrality of unmarked machine vision.

The relationship to otherness that is marked out for the non-holder of objective vision is also a central concept in postcolonial studies of science. Said describes this power relation in *Orientalism* where he proposes the construction of "The East" as being an example of an othering marked in opposition to the neutral position that is implied in The West (1978). As in the production of scientific knowledge discussed above, the apportioning of non-western sciences and knowledges as "other" finds it basis not in epistemic concerns, but in the material and cultural divisions of colonialism, as described by Polanco.

> *'The epistemological claim of the "universality of science" … covers what is an empirical fact, the material and intellectual construction of this "universal science"*

> *and its "international character." The "universality of science" does not appear to be the cause but the effect of a process that we cannot explain or understand merely by concentrating our attention on epistemological claims.'* (1992)

Polanco claims that "world-sciences", that is local knowledges or knowledge systems, generally come about as solutions to a set of local problems and functions so as to provide solutions to these problems and from this develop a form of epistemological unity. It is easy then in this way to see how through the colonialist expansion and global militarism through which European powers expanded their "local" area of concern to encompass the entire world so too European scientific knowledge became the solution to that of the expanded European "local" of the entire world.

The interplay between the existence of partial perspectives, situated or local knowledges and power is best categorised as a struggle over knowledge authority. Where authority denotes the power to decide what statements and practices are allowed to be categorised as science, legitimation denotes to whom, and by what means, this power to decide is granted.[18] This battle for authority is played out in a number of different ways throughout the formal institutions of scientific production, and in the wider social context. The dominant model for the way in which authority is produced in societies is that theorised by Max Weber. Weber defined legitimate authority as a tripartite structure divided as rational-legal authority, charismatic authority and traditional authority. These

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[18] Here we can see the difficulties proposed by and for liberal ideals of Enlightenment thinkers such as Mill, at the beginning of this chapter. The verification of scientific knowledge through the apparatus and structures of academic institutions which were generally available only to an affluent, white, European, male subsection of society meant that not only was the production of scientific knowledge constrained to this particular subset but the ability to validate or legitimate the production of such knowledge was also constrained to this subset and limited to any subaltern communities. That this subset was also overlapping with the subset of individuals who possessed legal and moral authority highlights the interrelation between the production of knowledge and other forms of authority.

can roughly be described as authority stemming from legal and bureaucratic structures, authority stemming from the charisma of a particular leading entity and authority stemming from tradition or custom (1978).

Scientific authority can also be suggested as being generated in a similar way as political authority. Whereas a traditional positivist approach to scientific work placed scientific authority within nature, or within the perceived neutral eye of the scientific instrument, the various studies and theories that have demonstrated science's socially constructed nature have shown that scientific authority is also generated as a function of the social environment in which science is produced. As such, scientific authority mirrors social and political authority. It is worthwhile noting that whilst constructivist arguments undermine the absolute objectivities of positivist scientific facts, "facts" are still very much operative within the production of authority. Facts play a role in the authority granted to a particular set of scientific statements, or within the legitimation of other statements. The way in which a scientific fact is given authority is through a process of legitimation. The process of legitimation for a scientific statement is perhaps best described by Lyotard who describes legitimation with reference to a legal definition as, 'the process by which a legislator is authorised to promulgate such a law as a norm' (1984, 8). In the case of a scientific statement this is expanded such that, 'a statement must fulfil a given set of conditions in order to be accepted as scientific. In this case, legitimation is the process by which a "legislator" dealing with scientific discourse is authorized to prescribe the stated conditions (in general, conditions of internal consistency and experimental verification) determining whether a statement is to be included in that discourse for consideration by the scientific community' (ibid.). Thus, we can suggest that knowledge is legitimated based on a combination of the authority granted to those making utterances (low epistemic profile) and on the basis of empirical facts (high epistemic profile).

The way in which scientific legitimation takes place then is with specific reference to the acceptance of experimental validity by a community (institution) that is deemed equal and competent with respect to the language of the statement such that approval and validation through argumentation (or inversely disproval through falsification) are accessible to the maker of the statement. In this way, it can be suggested scientific legitimation, or the legitimation of scientific authority, is expressly linked to Weber's description of political authority. Lyotard makes this point explicitly where he notes, 'The point is that there is a strict interlinkage between the kind of language called science and the kind called ethics and politics: they both stem from the same perspective, the same "choice" if you will – the choice called the Occident' (ibid.)[19]. We can then propose a model of knowledge legitimation in the same frame as described by Weber, in which rational-legal legitimation can be seen as parallel to the conventions of experimental practice, the accepted body of existing theory, and the theoretical frameworks on which these are built (again as described by Duhem-Quine), and the procedures and practices of the institutions from which legitimation is being sought. This portion of the legitimating process can be seen as having, as Foucault would describe, the strongest epistemic profile, whereas the charismatic and traditional authority, the referents of custom, institutional procedure and personality, can be seen as having little or no epistemic basis and are therefore primarily political functions.

It can be suggested that the political function that is not present in the epistemic portion of the production of scientific knowledge (regardless of whether the epistemic portion

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[19] Although it is beyond the scope of this thesis to discuss fully the socio-political and contextual underpinnings of the generation of authority with respect to gender or race, the interlinkages between the male voice and the concept of rationality is discussed in Beard's *Women and Power: A Manifesto* (2017). Meanwhile as seen in Mill's *On Liberty* and countless other examples the concept and idea of rational legitimate authority was generally seen as not applying to non-white oriental, African or other 'barbarian' communities. (Mill 2001)

claims the "strong objectivity" of partial knowledge or whether it claims the "pure" objectivity of positivism) is, however, tied to the non-epistemic portion through a process of reciprocal legitimation. This reciprocal legitimation takes place in the form of acceptance into, or within, institutional structures. Usually this takes place with reference to knowledge of the specific languages and codes of the institution but also through the ability to produce new knowledge (epistemic profile) within these codes (Lyotard 1984; Marcuse 1991, 162; Berger and Luckmann 1966, 110-1). In addition, the institution and its directions of research are linked to the decisions of funding that are themselves within a circular process of legitimation with economic, political and military functions that rely on the institution for their rational-legal authority. As such the type of knowledge produced which has a high epistemic profile, such as experimental research, is directly resultant from the struggles for power that are represented in the non-epistemic factors of knowledge production.

The possibility of an objective model with which to completely describe the world is thus a project that is imbued with a number of political and epistemological problems that become apparent when the claims of scientific and measuring objectivity or neutrality are examined more closely. In particular, claims toward single and authoritative objective viewpoints can be seen as denotative of political claims towards power over the heterogeneous viewpoints of other actors. As such it is possible to suggest that the Enlightenment ideal for a way of describing the world free from human subjectivity and politics is made no more possible through the expansion of global computation.

2.4 Conclusion – A Map of the World

It is important here, having moved through such diverse areas of theory, to summarise some of the key elements that have been identified, those that have been identified by other theorists and that which can be concluded from them. The first, and key element to be identified is the nature of knowledge that can exist within the structure of computing systems. As we have seen computation relies on forms of knowledge that are measurable, discrete and definite, in order that they can be held as external to the phenomena to which they relate. In other words, computation requires that for a phenomenon to be computed it must be translated into an abstract form in order that translations and manipulations can be carried out on that abstract rather than the entity to which it relates. This process of abstract representation can be fundamentally characterised as a measurement operation in which a real-world phenomenon is represented through an agreed system of encoding in order that it can be represented within some formal system. This formal system we have called an ontology – the way in which the world is represented within the system of knowledge. In fact, what we have proposed in this chapter is that computation is defined as that which acts on those representations themselves and through algorithmic action implies and instantiates effects in the physical domain through action in the abstract.

What we have also seen, however, is that systems of measurement and abstraction that describe the world are fundamentally limited in their ability to fully account for the complexity and subjectivity of its reality. We can suggest that they are not only limited in their application, but they are limited in their potential, by the limitations of formal systems in completely describing the world and by the difficulties of defining a system of objective knowledge. In other words, the attempt to map the world completely is limited by the fact that the map must always form a smaller part than the world itself and by the fact that the world exists subjectively in such a way as that no two maps may ever agree. As such, the abstraction of knowledge, the sensing of real-world phenomena and its translation into abstraction, relies on the deployment of agreed sets of assumptions about the relationship between the abstracted knowledge and the phenomena that it attempts to represent. These assumptions vary from measurement paradigm to measurement paradigm but irrespective of whatever choice is made, it is possible to suggest that computational knowledge results from a series of predetermined decisions around the classification, and measurement of technologically observable and translatable phenomena. As such it is also possible to suggest that those types of knowledge that cannot be construed as measurable in this way cannot be constituted in the body of computational knowledge.

That computational knowledge is limited in these ways is the feature that allows the communication of phenomena independent of the phenomena themselves and thus it is central to computation ability to work as a form of communication. Thus, the types of knowledge that are computable demonstrate how a trade-off between complexity and subjectivity is the requirement of communication. Communication, however, must not be thought of as an addition to computation but rather as a central feature of its ability to externalise knowledge in order that it can be acted upon within computation's abstract structures and in order that it can be legitimated within a system of legitimation that is predicated on the need for external validation. As computing technologies and computational knowledge expand throughout society so too the requirements of communication demand a universality of abstraction between the represented and the real. It is therefore possible to suggest that computation represents a subset of total knowledge, that which can be represented and communicated within shared abstract systems of representation.

Beyond the conceptual limitations of representation what we have also seen is that the results of the determination, classification and modelling of external phenomena as abstract representations are deeply influenced by the context in which the abstraction is made. As a result the abstract entities of computation are affected by the standpoint from which they are made, but also, as we have seen, the limitations of our understanding and the inequality of access to making legitimate claims towards knowledge act to further limit the breadth of the constituted body of knowledge. What we have seen is that claims towards a single unified objective model for the world are not only fraught with challenging political implications but are counter intuitive to the production of a science that is grounded in the experience of the world by individuals. Despite this we have seen that the prevalence of particular systems of knowledge and their claims towards authority help to reinforce their own dominance by legitimating and granting authority only to those types of knowledge that are consistent with the rules of dominant system in which knowledge is legitimated external to its holder. As such the expansion of computation acts to produce further knowledge that is consistent with the requirements of computation and acts to reinforce and legitimate its position as a dominant and objective knowledge system. In doing so, and as we will see in *Chapter 4*, this self-reinforcing structure acts also to legitimate computational thinking in ever expanding fields.

This relationship between computational knowledge and its legitimation is of importance because not only does computational knowledge exist as the result of power struggles for representation, but certain knowledges cannot be represented in the abstract, and so the expansion of computation creates a challenge for the continued existence and visibility of these forms of knowledge. Whilst some of the feminist and post-colonial studies work that we have explored suggest that a science that reflects subjectivities, or multiple objectivities exists as a solution to such challenges, the communicability required by computing technologies renders this at odds with the computation. It is therefore possible to suggest that the body of computational knowledge is not only that which can be represented but that in the representation there are also struggles for which version of this knowledge persists. In other words, at stake in computation is what parts of the world can be encoded and from whose perspective.

This chapter therefore develops an understanding of computation as system of processes that deal in abstracted representation, and we have examined how these systems of abstraction are imbued with the politics of authority and legitimation. This understanding, however useful, does not tell us much in isolation. As this study is concerned with the impact of these technologies on society it is necessary for us to examine the ways in which society is being restructured through its encounter with computation.

3 On the Structure of Posthuman Technosocieties

I am a scientist; but to be a technocrat would put me out of business as a man. Yet there I was, eighteen months ago, intent on creating a scientific way of governing. And here I am today, proud of the tools we have made. Why? – Stafford Beer

3.1 Introduction

Having surveyed, albeit in the cursory manner that this thesis allows, some of the theory that underpins computation and its relationship to abstraction it would be enticing to jump immediately into an exploration of the ways in which society is being reformed and regenerated around the systems of computation we have identified. It would be neglectful, however, to do so without first examining the work of other artists and theorists who have engaged in studies with similar, albeit varied, aims. In *2.2.1 Representation: A Critical Background* we introduced the concept of computational systems as based on the encoding and representation of the world through abstract structures. In this chapter we will examine how different artists and theorists have attempted to summarise, categorise and evaluate the ways in which computational systems and computational logic have acted as forces, entities and structures that interact with and produce new forms of existence.

It is important to note at this point that the strategy employed within this chapter holds relevance for the reading of this practice-based research thesis as a whole and of art practice research in general. Namely this thesis attempts to connect the practice and theory of particular moments under common headings and concerns in order to try and understand more completely the range of approaches and types of knowledge that artists and theorists have produced in response to the changes brought about by computation. The purpose of this chapter is not to create a complete art historical survey that encompasses all the types of work that has engaged with the concerns of computational societies, but rather to find examples of how art practice has acted to produce knowledge that is relevant to the understanding of the concerns of this thesis[20]. This approach reflects an understanding of the value of art practice as a form of research and as a form of meaning making that exists in parallel and in coordination with the academic and theoretical work with which it coincides.

Whilst this thesis has identified computation by using terms expanded far beyond the electronic substrates of modern computing machines much of the existing theory that deals with the interrelation between "society" and "computing technology" has focussed more particularly on the practices that have come about since the middle part of the twentieth century and that are intrinsically linked with the electronic and electrical systems on which they are formulated. *Section 3.2 Cybernetic Systems – Computational Structures* traces early cybernetics research and theory, through systems art of the nineteen-fifties to the more recent theory of Castells and others. Whilst at the time the term cybernetics was focussed on the application of computation and its logic to specific concentrated fields it is possible to suggest that contemporary society has become truly cybernetic – connected and controlled through the flow of information and information processing machines. The focus in this section on hardware and systems theory reflects the visibility, novelty and success of early computational infrastructures. Those features that appear most tangible and most novel have often been the subject of most discussion in both art and theory. In particular many theorist's have focussed on an understanding of society as a series of interlinked systems that mirror the cybernetic control systems

[20] For a good historical Shanken's *Cybernetics and Art: Cultural Convergence in the 1960s* provides a good understanding of the relationship between cybernetics, art and other related fields.

developed on computing and industrial machines and infrastructures. The visibility of these machines in the changing living and working environments of industrialised and post industrial economies, and the visible linkages of the telecommunications networks that expanded to connect them makes it no surprise that much of the critical practice and theory that examined these systems was focussed on their physical material and on making visible the concepts and structures that underpinned these complex networks.

As society increasingly restructured itself through and around computational technologies, the systems themselves have in many ways become less visible and less separable from that structure that we call society itself. So too the art and theory that has engaged with these developing subjects has become more diffused into a critique of society in general. This change from the large visible computing machines and novelty of systems theories can be suggested as a disappearance of some of those features from the contemporary consciousness. In parallel, as computing systems developed from single purpose electrical systems to general purpose electronic devices an increasing prominence within the field of theory was given to the role of software (although less so until more recently in the field of art practice – perhaps in part to do with its relative invisibility and its resistance to discreet capture and formalisation) – those abstracted entities and algorithms that occupied the cybernetic systems of computation. *Section 3.3 The Reprogrammable Matrix – Being Software* examines the way in which art and theory has tried to come to terms with the abstraction of the world into digital codes. In the work of those such as Haraway, Hayles, Davis and Laric one sees a rethinking of the world generally as a series of informational entities and processes contained on substrates both electronic and biological.

Finally, *Section 3.5 Protocols – Digital Membranes* examines the way in which the interaction of the hardware and software elements of computational society function to mediate and control the possibilities of existence. It can be suggested that this represents an examination of a society in which computation has further disappeared from view but which acts as a mediator for the social engagements that take place within it. In the earlier sections we expanded the definition of computation away from machines towards a wider field of practices. This section examines how the logic of computation informs these practices. From the form and application of contemporary power highlighted by Lash and Bratton to the responses of tactical media and instrumental art practices such as Critical Art Ensemble we will examine attempts to resist and uncover the political forces of contemporary computational societies. These investigations may thus appear less strictly focussed on computation, however, they deal with questions of power that are inherently networked.

Whilst these categorisations attempt to group art and theory within some common focus the boundaries of each are porous and the categorisations not exclusive of each other. In fact, in most cases the opposite is true inasmuch as a focus on one element generally precipitates an interaction with the others. In this chapter then we will examine proposals for the ways in which the hardware, software and protocols of the networks of computational systems are seen to reorganise ways of being and ways of doing. What can also be seen is that while these approaches are useful and enlightening the expanded understanding of computation that has been discussed in this thesis up to this point directs us towards an area that these approaches have failed to address – namely that they fail to sufficiently account for that fact that each of these elements and concerns are predicated upon the abstract representational structures we have already discussed.

3.2 Cybernetic Systems – Computational Structures

> *One can decide that the principal role of knowledge is an indispensible element in the functioning of society, and act in accordance with that decision, only if one has already decided that society is a giant machine. – Jean-François Lyotard*

In this thesis computation has been defined with terms that expand beyond the electrical, electronic and semi-conductor substrates of modern computing machines. Yet in doing so it would be incorrect to ignore the impact of these machines in the understanding of contemporary computation or in the impact they have had on the construction of contemporary society or the thought of artists and theorists who have tried to engage with it. These cybernetic systems of computation formed first in the military research facilities of the early twentieth century and whose existence rapidly multiplied in the period following World War Two gave rise to the thinking of society as a system of interconnected elements connected, like the machines on which they were modelled, through information conduits between nodes processing input and output signals.

This view of society as a system which expanded alongside computing machines was developed particularly from the work of Von Bertalanffy whose *An Outline of General Systems Theory* (1950) became a basis for the work of other prominent cyberneticists and systems theorists[21] such as economist Kenneth Boulding, political scientist Charles McClelland, psychologists William Ross Ashby and Anatol Rapoport, anthropologists

[21] The term cybernetics is used throughout this chapter to describe the work of those that were involved in the production and use of early computational systems and in the application of the concepts of computing developed in these systems to a wider field of operations. The use of the term cybernetics here overlaps with that of systems theory in the context of the expanded definition of computation that is used throughout this thesis.

Margaret Mead and Gregory Bateson, and later cyberneticians Stafford Beer and Gordon Pask. Despite coming to dominance in the post-war period of the late twentieth century – it is possible to suggest that systems theory logically and philosophically finds its roots in the ordering and categorising practices of states in the early modern period. As highlighted by Bauman, 'The ideal that the naming/classifying function strives to achieve is a sort of commodious filing cabinet that contains all the files that contain all the items that the world contains – but confines each file and each item within a separate place of its own (with remaining doubts solved by a cross-reference index)' (1991, 2). It becomes possible to propose that systems theory, or a systems understanding of the world of classified entities, as a logical next step after classification – a drawing of the relational lines between those objects which classification has made stationary. It also becomes possible to think cybernetics and systems thinking as tracing a direct route from the classificatory practices that were discussed in *Section 2.2.1*. There we saw that when the "system" in question, made of interacting and complex entitles, become represented and acted upon within the diagrammatic and schematic structures of cybernetics and computation the relationship between the model and the real becomes increasingly important.

Not surprisingly then, the systems theory that grew up out of the cybernetic, informational and computational systems that expanded rapidly in the post-war period brought an increasing focus on the importance of information and it's movement. Systems diagrams, and computational systems both operated in the abstracted domain of representation – acting as models of that which was represented. However. it is possible to suggest that what was conceptualised as "systems" were in fact models of systems, an important distinction that conceived of systems generally as information systems. Where information had first become an efficient processing proxy for that to which it pertained it became a subject in its own right. In other words, a systems diagram did not describe a system itself but an already abstracted version of it. Thus the focus of study was shifted to the abstract model away from that which was represented. The proliferation of physical networks carrying abstract signals and the theoretical understandings of systems theorists and cyberneticists modelling the world through hidden conduits of interconnection gave rise to an avant-garde movement in political and social theory that became a dominant framework in the production of art. Those who may be considered as cybernetic and systems[22] artists attempted to conceptualise the systems in which they operated, by foregrounding their operation as part of a wider system or by examining the implications of a society constructed and mediated by information networks.

One field where the attempt to understand this newly emergent systems thinking was prevalent was within the fields of minimalist, field and hard edge painting that had emerged by the mid nineteen-fifties. These fields of Systems Art attempted to conceptualise the role of systems thinking through artistic production of knowledge. Amongst other examples, it is possible to suggest that artists such as Frank Stella and Donald Judd used strict geometric form and repetition, both serially and internally, to highlight the structuring work of geometry as a readable fact of their work. This turn, it can be proposed, followed that of systems theorists to attempt to express the sense of order that was at play in structuring relationships between objects, as opposed to allowing hidden rules to operate beneath the surface of the work - as hidden and mediating systems. This artistic practice, which was contemporary to the theory, thus

[22] As with the theory of cybernetics and systems theory, there is a need to define some terms to describe a series of overlapping and intersecting art practices within this discussion. Doing so, perhaps in the discussion of art more than theory, can be fraught with difficulty as artists themselves along with critics often have a stake in their positioning within different categorisations. Here, however, as we are not attempting to chart an art historical overview it should be possible to ignore any such debates and for the sake of expediency to use a shorthand that allows us talk about a wide variety of practices under the umbrella of one term. As such the term Systems Art will be used here to encompass practices that are variously called Systemic Art, Hard Edge, Field Painting, Minimalist and Cybernetic Art which overlap but are not synonymous.

suggests itself for an examination of artistic attempts to engage with the issues raised by the increasing dominance and visibility of computing systems.

Stella is one such artist whose work can be suggested as demonstrating a concern for the increased dominance of systems as structuring forces. For example, *Turkish Mambo* (*Figure 3.1*) draws on strict interacting geometries positioned in the painting as object in their own right rather than referential to some outside referent from which their meaning was derived or for which it provided some illusory basis (Rubin 1970, 15). Thus, Stella's work seems to call into clear relief the interaction of elements through well-defined relationships, but further, the strict delineations brings forth the possibility that these relationships can in some way be quantified and made visible.

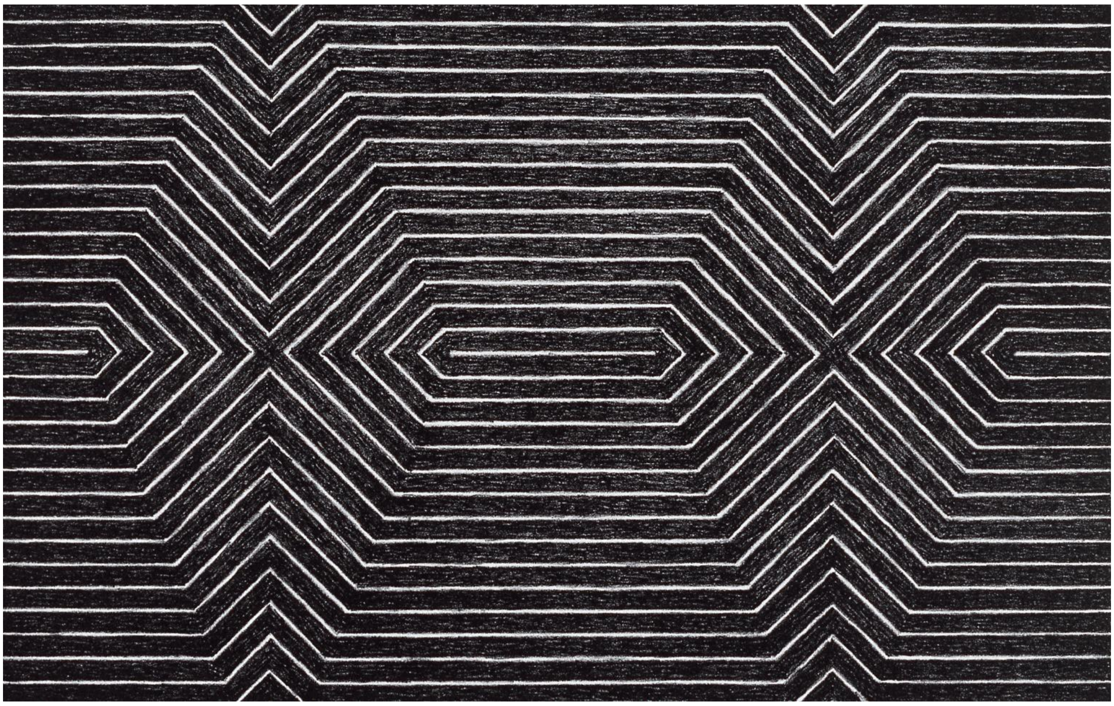

Figure 3.1 *Turkish Mambo*. (Stella 1959). Enamel on Canvas

Figure 3.2 Mach II. (Noland 1964). Acrylic Resin on Canvas

Figure 3.3 Untitled (DSS 120). (Judd 1968). Stainless Steel and Amber Plexiglas

As Alloway, the critic who organised the influential 1966 exhibition *Systemic Art* noted in his curatorial notes,

> *The field and the module (with its serial potential as an extendable grid) have in common a level of organization that precludes breaking the system. This organization does not function as the invisible servicing of the work of art, but is the visible skin (1966, 19).*

These Systems Art works then can be proposed as totalising diagrams of themselves[23]. Harries notes, ‘These kinds of art often do not stem from observations of things visible in the external natural environment, but from observations of depicted shapes and

[23] The idea of a map that is self-extensive is described in the following section with reference to Deleuze’s concept of the “diagram”.

relationships between them' (Harries 1981). In other words, these works operate at a level of explicit representation – not representations of other entities not present but of ordering systems that mediate the relationship between the objects that are present. Unlike the systems diagrams of cybernetics these works achieved a completeness that was possible only by referring to that which was contained within the works themselves. As such no encoding existed or was required between that which was represented and its referent.

If taking examples contemporary to the period, such as by Judd, Stella or work such as Kenneth Noland's (*Figure 3.2*), these works seemed to hide the human's role as part of the system in which the work operated, Alloway goes on to note that,

> *A system is not antithetical to the values suggested by such art world word-clusters as humanist, organic, and process. On the contrary, while the artist is engaged with it, a system is a process: trial and error, instead of being incorporated into the painting, occur off the canvas (1966, 19).*

What Alloway's comments describe is that the clean geometries of these works, as with the cybernetic systems diagrams, in some way obscure the underlying and messy processes that go into rendering these clean new geometries. This, it can be suggested, reflected a modernist tendency for clean diagrammatic and systematic orderings that follows from the Enlightenment's unifying ideals. Alloway's comment in fact somewhat foreshadows the crisis or limitations that these diagrammatic strategies would face. In this way early Systems Art can be suggested as purely being informational or diagrammatic - rather than representations of the wider systems of production of which the works are components, they represent the existence of a system that is contained totally within the works themselves. As such it can be proposed that these works act as an investigation of a way of thinking that at the time was being explored in systems thinking but which had not yet crystallised artistically into the formations of hardware and interconnecting networks that became more dominant later. Doing so, these works avoided the difficulties of rendering a diagram of a complex system both complete or total and fully consistent. In other words, in order to demonstrate the completeness of the ordering systems on the canvas the work was required to forgo the complexity of describing the wider systems outside of the canvas.

The limitations that were evident in the Systems Art works in describing the complexity of the systems outside of the work itself lead to a number of attempted resolutions operating in opposite directions in relation to the challenge at hand. At one end some artists attempted to understand the increasingly cybernetic reality by appropriating and examining the hardware elements from which the networks were made. Rather than contend with the idealised form of a totalising systems diagram it was instead possible to try to understand the reality and components of these burgeoning networks without assuming that their totality in accounting for the complexity of the wider world in which the art work operated. Instead information, feedback, heterostasis and flow became the subjects of a cybernetic art that more closely represented the reality of flow charts and diagrams of engineering cybernetics but which were applied in a concentrated way in order to examine the materiality of these subjects. Roy Ascott in particular typified this cybernetic turn and his texts *The Cybernetic Stance: My Process and Purpose* (1968) and *Art and Telematics: towards a network consciousness* (1984) set out his position that art science and politics must, and would, merge into a '*cybernetic vision*, in which feedback, dialogue and involvement in some creative interplay at deep levels of experience are paramount' (1968, 106). For Ascott, systems were dynamic and "behavioural" (2002) rather than formed of fixed entities and as such feedback, dialogue and interaction - in other words information transfer - were the primary features of the system, a point which will be further discussed in *Section 3.3*. Ascott was interested in the form of the cybernetic system as a structure for society and social relations and his work was an attempt to bring this into being through its elucidation in arts practice.

The burgeoning telecommunications networks brought visibility to the cybernetic systems of information transmission. This brought with it a field of media and cybernetic art that attempted to grapple with the questions of communication systems as they presented themselves to the public. Amongst others, the highly significant and publicly visible work artists such as Nam Jun Paik (*Figure 3.4*) and Steve Willats foregrounded the technological hardware of cybernetic systems through the technologies themselves employed by cyberneticists; analogue signals, video and light incorporated into work brought the physical networks proliferating through society into cultural consciousness. Paik who coined the term 'electronic super highway' (1974) used his media installations to interrogate the mediating effects of cybernetic systems, but as with Ascott and theorists such as Beer and other cyberneticists, he proposed the utopian potential of such technologies, proposing, 'Efficient communication also reduces social waste and all sorts of mishaps everywhere. The gains will be tremendous, environmentally and energy-wise' (ibid.). Willats in particular also employed the technology of the flow diagram into his work, first with *Homeostat Drawing* (*Figure 3.5*) in the abstract but later with information laden systems diagrams of human and socio-technical relationships.

Willat's arrows and Ascott's later telematics works both engaged the structures of a computationally driven society in its early stages. Both, however, like much cybernetic and systems art, focussed on the materiality of the structures themselves, on the hardware of communication, on how communication flowed between nodes rather than how the nodes themselves had a materiality and material impact on the information that flowed. Pask, an influential member of the cybernetics and systems theory community and president of the International Society for the Systems Sciences, bridged the art-practice/theory divide with *The Colloquy of Mobiles*. In doing so Pask's work points towards the importance of the variety of approaches, both artistic and theoretical, in the attempt to understand the technological developments of the time. Ascott's *La Plissure du Texte* (1983) and *Organe et Fonction* (1985), perhaps, most closely prefigure the computational structure of society that we have identified in this thesis. Despite focussing on the materiality of the network's hardware and structures both works strip the informational component (text) of context in a way that presupposes the abstraction relationship that we have identified as central to computation. This prefiguration, it is possible to suggest, did not give rise to a focus on representational underpinnings as the concerns of the piece and the surrounding artistic context focussed more heavily on hardware and network infrastructures than on the underlying representations.

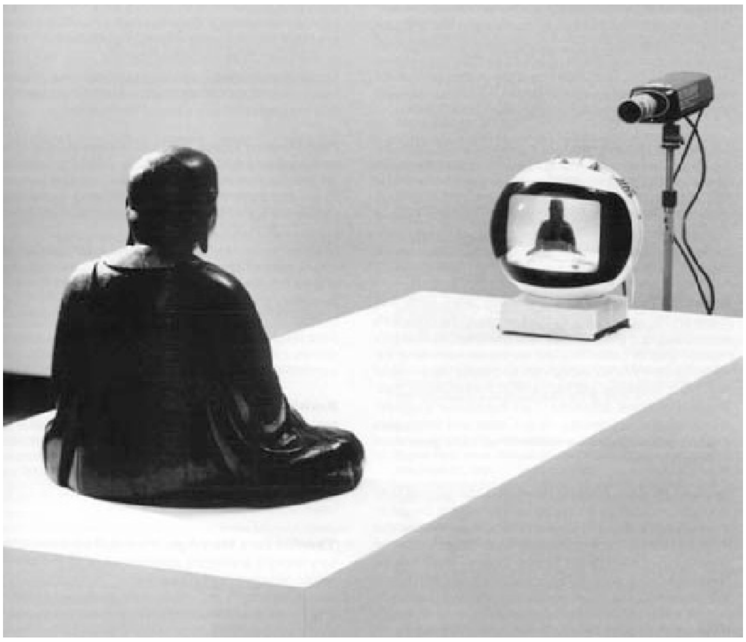

Figure 3.4 TV Buddha. (Paik 1974b). television monitor, video camera, painted wooden Buddha, tripod, plinth

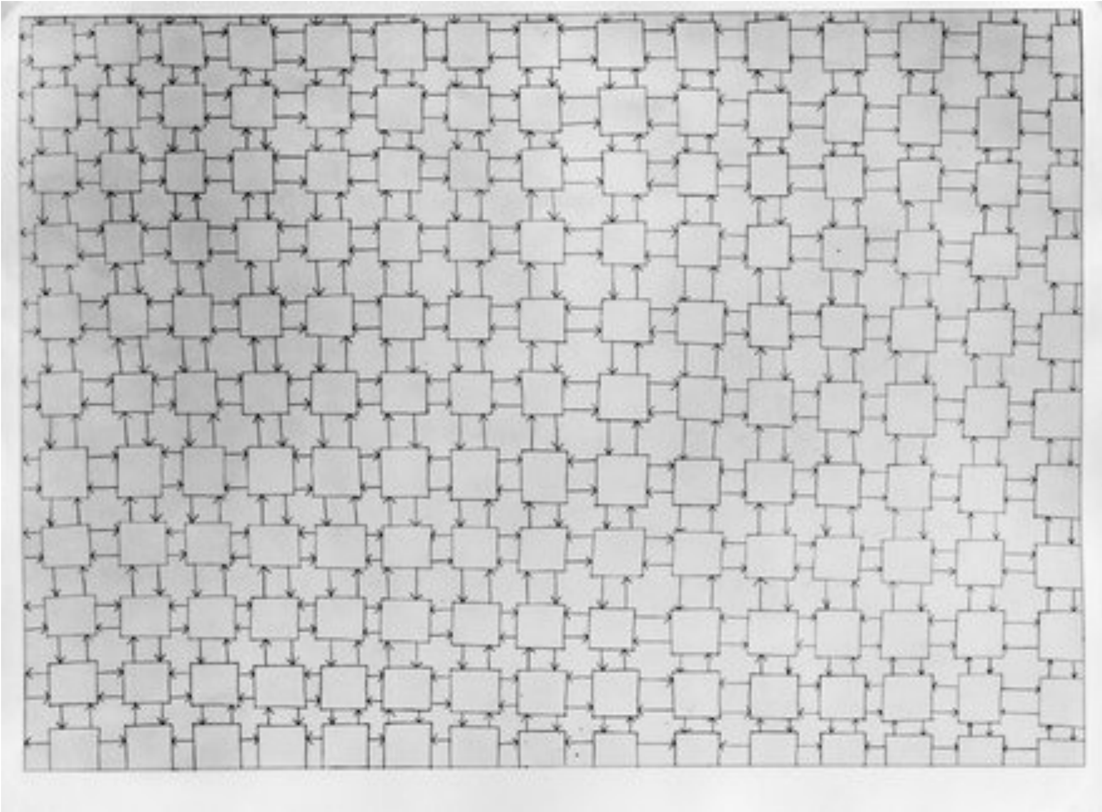

Figure 3.5 Homestat Drawing No. 1. (Willats 1969). Pencil on Paper

Whilst the cybernetic and media art practices discussed above attempted to follow the development of the technical structures of an increasingly cybernetic reality a parallel development in arts practice traced the problems presented by Systems Art in an opposing direction. Rather than examining the emergent technologies themselves other Systems Art practices attempted to explore the presence of systems outside of the canvas. In a way that reflected the increasing complexity of cybernetic approaches a number of artists of this period attempted to grapple with the existence of the artwork in a much wider system of operation. This approach, such as in the work of Dan Graham such as *Public Space/Two Audiences* (*Figure 3.6*) and Daniel Buren's stained glass and installation works can be suggested as building upon the acknowledgement of a systems presence in which the viewer was embedded. In particular the use of transparency, mirrors and gallery surfaces stretched the representation of system beyond the act of painting itself. As such, unlike the example of Stella there was an acknowledgement that the system included elements not contained within the canvas and which could not fully be described by its geometry. Thus, these later works can be suggested as attempting to encompass a wider field of operations, not least of which is the perception of the work itself. Similar to the minimalist and hard-edged pieces these works displayed an increasing preponderance with the idea of systems as mediating existence. That these systems were increasingly conceptualised as diagrammatic was perhaps reflected in the geometric orderings that typified this work. These works it can be proposed attempted to expand the investigation of system beyond that which was contained within work and in doing so beyond that which could be totally described by the diagram.

The dissolution of the materials of cybernetic systems into the functioning of everyday society in many respects made them disappear as explicit subject. With this, much of the contemporary practice developed into more distinct and specialised forms as cybernetic technologies became the norm in everyday life. Much conceptual work that followed sought to encompass more fully the myriad mediating systems and information flows through which they deemed society was constructed. Work such as Rauschenberg's *Erased de Kooning Drawing* (1953) or that of Joseph Kosuth (*Figure 3.7*) and Lawrence Weiner became less diagrammatic and through a postmodern sensibility towards greater subjectivity and embodiment became less obviously embedded in the cybernetic information systems that could be described through the nodes and arrows. It is thus possible to suggest that the difficulties of presenting totalising diagrams for describing what postmodernism had suggested as a more contingent and subjective construction for society was reflected in this turn. This turn in practice was reflected also in theory, the work of postmodernists such as Lyotard and in the non-human centred theories discussed in the next section broadened the understanding of systems such that it jumped ahead of that which could be captured in cybernetic diagrams.

Figure 3.6 Public Space/Two Audiences. (Graham 1976). Two rooms, each with separate entrance, divided by a sound-insulating glass panel, one mirrored wall, muslin, fluorescent lights, and wood

Figure 3.7 One and Three Chairs. (Kosuth 1965). Wood folding chair, mounted photograph of a chair, and mounted photographic enlargement of the dictionary definition of "chair".

This dissolution and specialisation meant art practices and theory dispersed to address individual fields of action within a cybernetic network society. Once the computer network became an essential part of society, different approaches to understanding these systems proliferated. With this, the focus tended away from the hardware and structure of the cybernetic systems and towards its informational content. As access to the computer structures, that in the earlier days of cybernetic systems seemed the reserve of state, military and research institutions proliferated, so too did access to media and computational tools and materials. While many artists and more theorists continue to probe the shifting edge of technological capability much of the work shifted its focus to the new practices of living brought about by newer tools. Those practices that remained with technology as their foreground often focussed more on technologies' capabilities as a way of enabling artistic practices rather than on practices as a tool to explore technologies themselves. In the *Section 3.3* we will follow the trail of this dissolution, however, before doing so it is worthwhile to examine a current practice that demonstrates the emergence of a new cybernetic boundary, that of the machine and the body.

Whilst there exist many practices that are focussed on hardware, infrastructure or systems theory, practices of bio-art at the periphery of scientific capability form a sort of archaeology of the future that is of interest to our understanding of the changing relationship between human and computation. By creating fragments of what may not only be possible but what may become normal through technological advancement these practices push at the boundaries of human-machine relations. These hardware-focussed examples can, however, give clues to the changing boundary of human and cybernetic systems that will appear in *Section 3.3* but which trace a lineage back to the work of artists such as Paik. One such example amongst many, is Wafaa Bilal's *3rdi* (*Figure 3.8*) which consisted of a camera implanted into the back of the artist's head to record images and upload them directly to the internet during a trip through Iraq producing images in the opposite direction of the artist's viewpoint. In doing so the optical strategies of the person become reversed, the movement of eyes, the focus, the attention and the context are all removed to be replaced by a GPS located time stamped image. As Bilal notes, 'It is anti-photography, decoded, and will capture images that are denoted rather than connoted, a technological-biological image' (2017). New hardware focussed practices such as this point towards a blurring of the lines between computer and machine. A blurring that draws on the early work of artists and theorists that we have examined but which, rather than focussing on the material and hardware of the network concerns itself with that which flows across it.

Figure 3.8 3rdi. (Bilal 2010). 3rdi (implanted camera), Silver, ABS, USB Cable

3.3 The Reprogrammable Matrix – Being Software

> *Know that which is pervading all this is indestructible. No one is capable of destroying it. – Baghavad Gita 2.17*

At the outset of this chapter we identified the need to examine work that has explored the shifting human-machine relations brought about by computation. The previous section examined work that engaged with the novelty of visible computing infrastructures and the systems thinking that accompanied them. This section examines work that, accompanying the dissolution of these systems into society, focuses on those less visible elements of these technologies, those which flowed across their network – information, signals and software. The development of the physical cybernetic technologies discussed above led to a necessary and parallel focus on that which flowed across the network – namely information. Stemming from the seminal work of Shannon in *A*

Mathematical Theory of Communication (1948) Information Theory developed as a discipline that explored the transmission of information as digital codes across the analogue infrastructures of early computation. As with Bertalanfy's general systems theory the application of Shannon's work spread amongst the cybernetic and systems theory fields beyond the realm of electronic machinery into varied studies of human and other biological and non-electronic systems. In the context of the cybernetic and systems theory that focussed on systems composed of information, information movement and processing became a subject in its own right. This informatics focus is discussed by Hayles, who notes of the Macy Conferences[24] that information was the central and most important feature of a systems organisation.

> *The triumph of information over materiality was a major theme at the first Macy Conference. John von Neumann and Norbert Wiener led the way by making clear that the important entity in the man-machine equation was information, not energy.[…] Central was how much information could flow through the system and how quickly it could move. Wiener, emphasizing the movement from energy to information, made the point explicitly: "The fundamental idea is the message . . . and the fundamental element of the message is the decision." Decisions are important not because they produce material goods but because they produce information.* (1999, 51-52)

[24] The Macy Conferences were a series of meetings between scholars from a wide field of areas that are probably most famous for the conferences on cybernetics that occurred between 1946 and 1953. Contributions to the conferences included the work of Warren McCulloch, John von Neuman, Claude Shannon, Alan Turing, Gregory Bateson, Margaret Mead, Heinz von Foerster, Humberto Maturana, Franciso Varela, Warren Weaver, Norbert Wiener and many others. The conferences were notable for their presentation of unfinished work that lead to intensely interdisciplinary discussions (Hayles 1999, 50-51).

The thinking of the world as composed of information systems necessarily meant rethinking of human relations in information theoretic terms. Cyberneticists such as Bateson, McCulloch and Wiener began examining the idea that human thought and consciousness may exist in terms described by Information Theory, with the brain acting similarly to, if not the same as, the cybernetic machines called computers. McCulloch, for example, a psychologist and mathematician described his work with psychologist and psychiatrist Eilhard von Domarus as opening up the possibility that consciousness and ideas could exist independently within a human brain as in a computer (1974). With this understanding he went on to develop the concept of neural networks with Pitts in which the functioning of brain processes were modelled in the cybernetic terms of signals, feedback and control logic (McCulloch and Pitts 1990). In parallel to the work of McCulloch and Pitts, Wiener a philosopher mathematician (and sometime designer of anti-aircraft targeting systems with Julian Bigelow[25]) developed the first formal theory of cybernetics in *Cybernetics, or Control and Communication in the Animal and the Machine* (Wiener 1948). Wiener too proposed the possibilities of artificial intelligence and modelled intelligence as existing as a software sitting equally upon computing technologies or the biological substrates of the human and animal. This approach built upon his application of information and systems theory to behavioural systems which furthered the application of mathematical modelling to natural and stochastic process (Rosenblueth, Wiener, and Bigelow 1943).

Concurrent developments in biology such as the discovery of DNA by Watson and Crick (1953) added further weight to the cyberneticist understanding that beneath the human and animal “machines” lay mathematical software-like codes and processes that could be understood in the same way as those being worked with on computers (G. Dyson

[25] A discussion of Bigelow and Wiener’s work in the creation of aircraft targeting systems and the impact of this work on the creation of first and early programmable computers is contained within George Dyson’s *Turing’s Cathedral: The Origins of the Digital Universe*.

2012). The reproducibility and self-replication of codes that appeared present in an emerging understanding of DNA was being trialled within machines by computer scientists such as Von Neuman (1966) and Barricelli (described in F. Dyson 2008). Both attempted to develop self-reproducing automata – digital beings existing solely of code and occupying the digital landscape of early computer memory. The impact of this work, alongside the successful application of computing to many other fields, suggested to many that humans may exist in the form of software on a biological hardware and also that perhaps it would be possible to reproduce similar and different forms of life that would be neither fully electronic or biological and perhaps bound by neither.

The intersection of mind and machine that was precipitated in the early development of cybernetics gave rise to various investigations of the boundary between human and machine. One area of study that pays particular focus to the investigation of this boundary between the human and the machine, and which follows the questions of whether human codes could exist independent of human bodies, is the area broadly termed posthumanism. Alternatively called Transhumanism or Cyborgism and overlapping with certain portions of object-oriented philosophies that trace their lineage to the cybernetic theories of those discussed above. These various discourses into the changing nature of this boundary have progressed in different ways. Whilst some have focussed particularly on the boundary and relationships between the organic-human and non-human machines, other more strictly termed posthumanist accounts have explored the simultaneous dissolution of the boundaries of all organic and non-organic material and cultural entities and processes. This difference can be seen as expressing a different understanding of the hardware and software relationships of a computational society – where the latter approach questions the existence of the human as a machine that is ontologically different to the range of other machines, living, inanimate and electronic on which the codes, protocols and software of society are played out.

The terminology here is entangling. This latter philosophical approach, for which we will use the term Posthumanism, also has a connected, albeit divergent, ideological approach which is more commonly called Transhumanism. Transhumanism, although sometimes applied to both fields is more commonly connected with ideas of human centred enhancement through the use of advanced technologies – such as human genetic engineering, neural implantation and human machine hybridisation, neural, cognitive and physical pharmacological enhancement and ultimately mind uploading and hybridised external human machine computation. This ideologically futurist Transhumanism, which has as its adherents prominent Transhumanist thinkers such as Raymond Kurzweil (1999)(2005), generally envisages a hybridised human machine assemblage wherein consciousness is contained in various degrees on networked biological and electronic substrates. Central to the Transhumanist ideology is the view of consciousness as software that is constrained upon the biological substrates on which it currently exists. As such ways to release it from these constraints can be developed. Whilst some such as O'Connell have highlighted the mystical and quasi-religious tendencies of such assumptions (O'Connell 2017), the Transhumanist position follows a route that places human and machine cognitions within the domain of information processing. Thus it can be suggested that it traces the line of those such as Shannon and Turing, through the early cybernetics research into the artificial computational life forms of Von Neumann and Barricelli, into the present position in which the cognition of humans and machines would be blended upon electronic computational substrates and electro-biological interfaces (Kurzweil 2005).

Although the field of Transhumanism is a relative outlier in academic research it is, as mentioned earlier, related to a more academic and philosophical field of research broadly termed Posthumanism. Posthuman discourses fit more generally within a range of theories that deal with non and less human-centred understandings of society. It is necessary to discriminate here and to explore those that seem most relevant to the particular subject of this thesis – that is the perceived convergence of being and representation within a generalised computer ontology. So, whereas, the non-human centric philosophies and strategies employed by theorists such as Baudrillard (1981), Deleuze and Guattari (1987), Latour (2005), DeLanda (2006) and Bennet (2010) provide welcome methodologies and techniques for thinking through the changing relationship between human and non-human agents – their focus tends towards technological and social assemblages that are broader in scope than is required here.

The Posthuman discourses that we will explore in this section sit between the two poles of non-human centred research and the more technical cybernetic and Transhumanist positions. This work deals with the shifting membrane between human actors and non-human computational systems within a context informed by these changing technologies and situated within a context of social conditions. Two such theorists whose work is particularly relevant here are Haraway, (whose work on scientific objectivity we discussed in *Section 2.3*) and Hayles (whose description of the Macy conferences was referred to above) both of whose work deals specifically with computational systems and the changing politics they engender. Unlike much of the transhumanist literature, their work is grounded in existing and developing realities rather than speculative technological propositions and hoped for politics.

Haraway's influential work *A Cyborg Manifesto* (1991) sets out a number of changes that she sees a digital informatics society catalysing. These she proposes mark out a break from a dichotomous human-machine society with an unchanging "nature" or "society" as transcendent fields of operation (*Table 3.1*). Whilst it is not necessary to explore each in detail it is worth looking at some of the transitions that she highlights and that are most relevant to the work of this thesis. Changes such as; Representation > Simulation, Organism > Biotic component, Physiology > Communications engineering, Heat > Noise, Perfection > Optimisation, Reproduction > Replication, Organic sex role specialisation > Optical genetic strategies, Mind > Artificial intelligence, (ibid, 162) identify a shift that highlights the reconstruction of society in informatics terms. Haraway's transformations make clear a vision of the world in which the traditional forms of domination through physical, centralised and symbolic orders give way to the existence of new forms of domination through the digital processes of information control. What these transformations also highlight is a posthuman vision in which that construction, biology and identity of the person becomes integrated within the ecosystem of the machine, and the architecture of the machine becomes the integrated ecosystem of the organism. As such she proposes the classically formed divisions between animal and human, mind and body, organism and machine, and nature and culture become increasingly porous and at times completely dissolute. Haraway contends, 'No objects, spaces, or bodies are sacred in themselves; any component can be interfaced with any other if the proper standard, the proper code, can be constructed for processing signals in a common language' (ibid, 163).

Haraway's proposal is a radical call for reorganising the classical division between different hardwares – human, biological and machine. This reorganisation, however, makes sense only in the context that all which exist on these hardwares are already decided as being many different codes or softwares. In a cyborg reality where the historical hardware divisions of bodies and machines dissolve as culture, existence and identity become played out in the representational codes of software.[26] In this view of

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[26] It is important here to highlight the use of the word representation in Haraway's text and discuss its relationship to the use of the word within this thesis. Haraway identifies what she sees as a change from representation to simulation in the change from 'comfortable old hierarchical dominations to the scary new networks' (1991, 162). Representation in Haraway's terms seems to align with a semiotic relationship between some "real" entity and its representation where the relationship has as its basis some field undefined but external to itself, perhaps culture, society or domination. Simulation then breaks this connection to the real, the simulation becoming entire in itself. Baudrillard captures this idea, 'Whereas representation attempts to absorb simulation by interpreting it as a false representation, simulation envelops the whole edifice of representation itself as a simulacrum' (Baudrillard 1981, 152). In the terms used in this thesis, however, the

computational societies the human actor becomes a programmable software node mediated through protocols with the other entities. The specifics of hardware recede and the function of society becomes one of information control (software).

> *In communications sciences, the translation of the world into a problem in coding can be illustrated by looking at cybernetic (feedback-controlled) systems theories applied to telephone technology, computer design, weapons deployment, or data base construction and maintenance. In each case, solution to the key questions rests on a theory of language and control; the key operation is determining the rates, directions, and probabilities of flow of a quantity called information. (ibid, 164)*

Organics of Domination	**Informatics of Domination**
representation	simulation
bourgeois novel, realism	science fiction, postmodernism
organism	biotic component
depth, integrity	surface, boundary
heat	noise
biology as clinical practice	biology as inscription
physiology	communications engineering
small group	subsystem
perfection	optimization
eugenics	population control

simulation still remains a representation – however, representation becomes the terms of its existence. It becomes represented within a computational system and so it exists – it exists in optical space. That it can exist within this system without reference to a real entity, or that the real entity to which it may initially have been connected can become subordinate to it does not diminish its presence as a representation within the terms of computation.

decadence, *Magic Mountain*	obsolescence, *Future Shock*
hygiene	stress management
microbiology, tuberculosis	immunology, AIDS
organic division of labor	ergonomics, cybernetics of labor
functional specialization	modular construction
reproduction	replication
organic sex role specialization	optimal genetic strategies
biological determinism	evolutionary inertia, constraints
community ecology	ecosystem
racial chain of being	neoimperialism, United Nations humanism
scientific management in home/factory	global factory/electronic cottage industry
family/market/factory	women in the integrated circuit
family wage	comparable worth
public/private	cyborg citizenship
nature/culture	fields of difference
cooperation	communications enhancement
Freud	Lacan
sex	genetic engineering
labor	robotics
mind	artificial intelligence
World War II	Star Wars
white capitalist patriarchy	informatics of domination

Table 3.1 *Transition from the comfortable old hierarchical dominations to the scary new networks of informatics of domination*. (Haraway 1991)

If Haraway's manifesto, written in 1985, and the changes she identified were portentous of a cyborg reality that seemed to be developing at the time, Hayles notes that the current technological reality, and the seeming technological future is somewhat more dispersed than in the creation of organo-machinic compound being. (Albeit transhumanist visions would suggest the game is not yet over.) She says,

> *At the center of these formations, transforming the conditions of life for millions of people, are networked and programmable media, and they are impacting everything from sensorimotor functions and non-conscious cognitive processing to national political discourse and transnational economies. Given the complexities of these dynamics, the individual person – or for that matter, the individual cyborg – is no longer the appropriate unit of analysis, if indeed it ever was. At issue now (and in the past) are distributed cultural cognitions embodied both in people and their technologies. (2006, 160)*

Hayles' approach, then, is to define a societal organisation around computation and cognition. It is possible to suggest that her focus is more purely on the way in which information acts rather than its place on the substrates on which it sits. Hayles uses the term the "Regime of Computation" to define a characteristic dynamic of society in which computation has seeped outward from the porous boundaries of electronic computer architectures, 'into every aspect of biological, social, economic and political realms but also into the construction of reality itself…' (2006, 161). In Hayles' conception computation takes place at all levels and upon any form of material substrate, electronic, human and non-human alike (2005, 17). In fact, in highly technologically developed and networked societies she notes, 'human awareness comprises the tip of a huge pyramid of data flows, most of which occur between machines' (2006, 161).

Hayles' cognisphere is a society in which reprogrammability and mutability are central aspects. Our co-development beside computing machines and through computational frameworks constantly reorganises human and non-human subjects that are generated and regenerated like universal Turing machines (1999)(2005)(2006). For Hayles then the focus can also be seen as being on software – inasmuch as she defines cognition as information processing – but hardware must also be considered as the necessary substrate. However, unlike in Transhuman or cyborg understandings the differences in hardware are still existent but the information becomes agnostic to the difference. In other words, in a regime of computation the flow and manipulation of information become the necessary unit of analysis and the substrates become secondary actors. Rather than dissolution of physical boundaries Hayles' vision presents more of dissolution of functional differences – human and machine actors become organised around the movement of information. The societal form that must follow then is no longer human centred, or machine centred but centred around transfer of information.

Despite this lineage from the classificatory practices of measurement through systems theory and cybernetics to thinking through the world as composed of information, it can be suggested that the importance of the measuring relationship in the production of this information remained relatively unexplored. Instead the focus of artists and theorists, as we have seen in this section, was more commonly on the way in which this information existed upon different substrates and as such whether it was possible to think of all information within the framework of similar codes. Despite this rich area of scholarship and research into the reprogrammable structurings of society there was little accompanying research through arts practice until more recent years. As we saw in *Section 3.2* the practices that seemed to examine burgeoning software constructions (such as that of Ascott) tended to do so primarily in the context of the hardware of the systems on which they were communicated. In some respect this may reflect the crisis that seemed to appear in the practices of systemic or minimalist art in which the clean diagrammatic forms of cybernetic systems seemed incapable of accounting for the complexity of the realities of the complex systems in which the world was embedded. Hayles identifies this moment of potential crisis in the Macy conferences and points towards a dualistic split in the search for what must be either a total or a functioning systems model – but not both. She notes,

> *When information is made representational, as in MacKay's model, it is conceptualized as an action rather than a thing. Verblike, it becomes a process that someone enacts, and thus it necessarily implies context and embodiment. The price it pays for embodiment is difficulty of quantification and loss of universality. […] Making information an action links it with reflexivity, for then its effect on the receiver must be taken into account, and measuring this effect sets up the potential for a reflexive spiral through an infinite regress of observers. Homeostasis won in the first wave largely because it was more manageable quantitatively. Reflexivity lost because specifying and delimiting context quickly ballooned into an unmanageable project.* (Hayles 1999, 56-57)

Here, as before, we see the same challenges that affected Systems Art in trying to create a model that was both sufficiently complete to contain the necessary detail of describing that which it attempted to describe and at the same time was sufficiently complete so as not to constantly expand in infinite complexity and as such become incapable of consistency or communication. This challenge which was discussed in *Section 2.2.1* and which was identified by Gödel is not only a question of technical complexity but of the limits of models themselves and foreshadows a central problem of information theory that will be discussed later in *Section 4.3.3* in which the possibilities of both total communication and infinite subjectivity become impossible under the conditions of network communication.

Both Hayles and Haraway thus, drawing on information theory, position their enquiries around the subject of information for which a definition is not sufficiently developed. One approach to capturing such an amorphous subject is through the archaeology of the practices and objects through which it is manifest. Manuel Castells, who conceptualises the network and the exchange of information across it as having become the defining structural form through which societies are shaped (1996), takes this approach. Contrasting with the more philosophical proposals of Haraway and Hayles, Castells sets out his position that the technological and social changes he discusses are inseparable from each other and that there exists no hierarchy of societal or technological determinism underpinning the other (1996, 5). Castells identifies the boundary of his investigation around a series of technologies that he calls “the net”.

> *Among information technologies, I include, like everybody else, the converging set of technologies in micro-electronics, computing (machines and software), telecommunications/broadcasting and opto-electronics. In addition, unlike some analysts, I include in the realm of information technologies genetic engineering and its expanding set of developments and applications. This is not only because genetic engineering is focussed on the decoding, manipulation, and eventual reprogramming of the information codes of living matter, but also because biology, electronics and informatics seem to be converging in their applications, in their materials, and more fundamentally in their conceptual approach…* (1996, 29)

Castells’ approach, although differing from those already discussed, also points towards the same information-centric reorganising principle for society, where even the genetic code of living matter is available for reprogramming within the framework of digital technologies. His approach, however, focuses more on the form that the information-centric society must, or has begun to, take – that of network. For Castells the form of the network exists to explode existing geographical and territorial boundaries – expanding the individual sphere of action through the electro-physical conduits of the network. As with Hayles, this sense of form is related to the existence of society as software but for Castells the transformation exists from the human boundary outward. Castells thus positions the primary reorganising force of computer architectures at what could be described as the software layer, even though its effect and expression appear in the form of the network. In his conception programmability, reprogrammability, reproducibility, transferability and manipulability escape from the digital substrates of computing machines and become reorganising principles for society at large reforming the subjects, objects and subject-objects with which they interact. In Castell's model, it can be suggested that society becomes a single supercomputer with information flowing through it. The manipulation of this software layer, information flow, begets the form of network rather than flows from it. Unlike the work of Haraway and Hayles, however, and perhaps reflective of his sociological background the unit of analysis e.g. the human is not fundamentally changed but rather the world of social relations in which they are embedded and which act upon them becomes changed.

This increasingly common understanding of the importance of reprogrammability and transferability in modern computationally mediated societies i.e. the focus on software rather than the previous focus on visible machines and circuit diagrams, began to yield some response within the research fields of contemporary art. In particular, bio-art practices at the edges of understanding of what can constitute a substrate by creating human-machine hybrids or heterotic assemblages. Stracey, however, notes that for much of this bio-art practice the driving force is often acritical, 'their rationales and justifications for turning life into art often remain hidden behind aestheticism or scientism, or rather glib "because I can" attitudes' (2009, 496). Nevertheless, some bio-artists or bio-art pieces successfully hint at the underlying software construction of society that is presented through this informatics understanding.

One such piece is Marc Quinn's *A Genomic Portrait: Sir John Sulston* (*Figure 3.9*) in which the human DNA becomes the figure of representation of the person. Of interest in the context of this research, however, is that Quinn does not use the DNA decoded, but reproduces the DNA disembodied in agar, in this way not only is the code available but the decoding is still an available site for applying the representational transformation by which the code is produced from the living entity. The portrait sits somewhere between the critique of bio-genetic practices and bio-informatic representation by leaving the possibility of understanding the material only within the physical domain as a by-product of medical process. Another project that examines the informatics turn and increasing importance of representation with respect of substrate in computational societies is *Microvenus* (2000) by Joe Davis. *Microvenus* captures the multi-layered process of representation and abstraction existent not only in computing technologies but at the interface between living things and computing technologies. By using "living" human DNA to encode a binary sequence that itself encodes an image of human reproductive organs Davis creates a circular loop of abstracted and physical entities; in each step the boundary between a physical entity of message carrier is dependent on the position in the loop that is employed.

Figure 3.9 A Genomic Portrait of Sir John Sulston. (Quinn 2001). Stainless steel, polycarbonate agar jelly, bacteria colonies, human DNA

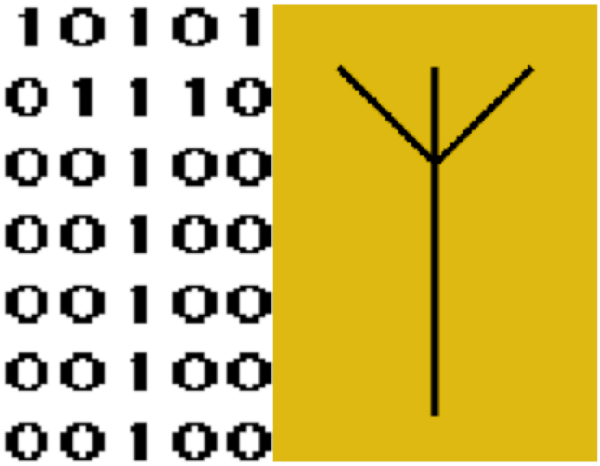

Figure 3.10 images from Microvenus. (J. Davis 2000). Image encoded in genetically modified DNA molecule

Both Quinn's and Davis' work it can be suggested are of interest in the context of this thesis as they approach in some way the expanded definition that this thesis has used for computation by exploring the way in which DNA codes act as a represented abstraction of the protein pairs from which they are formed. In doing so, however, the focus tends towards the fact of these structures of carriers as actual codes rather than interrogating the relationship between the physical protein and its existence as code, or the difference in its existence in abstracted and physical form.

Common among these artists and theorists there is the focus on the reprogrammability of the software codes that sit upon the human and machine substrates of contemporary society. Despite this focus on what may be called the software layer of society – a position that seems to accept the proposition of early cybernetics – little of this work delves into the relationship between the software representations and the physical entities to which they pertain. As we discussed in *2.2.1 Representational Systems – Abstracting the World* a modelling relationship exists between the physical domains of existence and the numerical domain of abstract representation. Investigation of this gap remains somewhat elusive in the practice and theory of the reprogrammable matrices of a computational society.

Despite this lack some artists have, however, begun to examine the idea of wholly abstracted entities and the increasing tendency for meaning making to occur primarily in interaction with these abstracted representations. Ubermorgen's *Psychos Sensation* (*Figure 3.10*) for example explores representational diagnosis through the digital flip-flops of a flow diagram. In a digital diagnosis platform, a "patient" responds to questions relating to their mental health and is guided through a series of unending questions based on their choices. Here, the condition of the patient becomes secondary to the represented patients' selection of variables, mirroring the increasingly algorithmic nature of decision-making processes in practices such as health but calling into question the idea of patient, or subject, as a series of digital answers to diagnostic questions.

Similarly Heath Bunting's *The Status Project* (Bunting 2004) employs the optical strategies of state classification. He processes the individual's status in contemporary society through simple algorithmic means. Bunting's work, as with Ubermorgen's is more generally focussed on the neo-liberal politics of modern states – addressing what exists as the potential outflows of a logic of computation in contemporary statecraft albeit without directly questioning the representational processes of measurement that lies beneath. As with *Psychos Sensation*, Bunting's work questions the way in which contemporary decisions move through the flow-chart logic of algorithms creating new types of subject and withholding forms of subjectivity (*Figure 3.11*).

Oliver Laric's ***圆明园3D*** (*Figure 3.13*) and *Lincoln 3D Scans* series perhaps come closest to an examination of the conditions of representation we have discussed. His work compresses the distance between representation and object through the creation of a digital double. By making available the scans on the internet Laric also questions the primary relationship between entity and representation – in the optical strategy of the network visibility becomes existence – as such the scans become the first available point of departure to the works themselves. More importantly, however, Laric's work exposes the limitations of representation of the object as purely geometric and optical entities – devoid of the physical materiality of the objects themselves. As with Bunting and Ubermorgen's work Laric's points towards a wider or deeper structuring force for contemporary technological relations that remains unresolved in the works themselves. One recent example that is worthy of mention is Too Much World: Is the Internet Dead? by Hito Steyerl (2013). Steyerl, whose essay also references Borges, suggests that the world of representation reaches into the real just as the real is represented in the images she describes. Thus, she hints at the convergence that this thesis identifies, positioning it in the visual domain as an excess of images flowing between the digital and the real for new heterotic compositions of human and machine eyes. Her work is a timely provocation, but as with others the underlying requirements of representation remain unexamined.

Figure 3.10 Screenshot from Psychos Sensation. (Ubermorgen 2014b). Web-enabled application

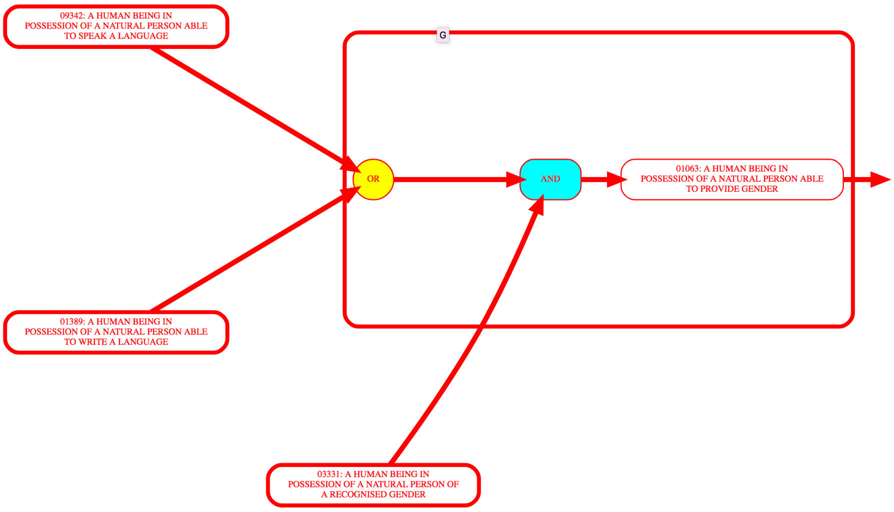

Figure 3.11 Screenshot from The Status Project. (Bunting, n.d.). Website

Figure 3.12 Screenshot from 圆明园 3D. (Laric 2013b). .obj file

Figure 3.13 Screenshot from Lincoln 3D scans. (Laric 2013a). .obj file

3.4 Protocols – Digital Membranes

> *A fifth bit indicates permission to execute the file as a program. If the sixth bit is on, the system will temporarily change the user identification of the current user to that of the creator of the file whenever the file is executed as a program. This feature provides for privileged programs which may use files which should neither be read nor changed by other users. – The UNIX Time-Sharing System*

In this chapter we have surveyed practice and theory that has engaged with the visible and less visible aspects of computing machines and computing logics. Much as a concern with software was necessitated by the relative disappearance of large computing machines the work in this section deals with forms of computational logic that are not easily given to visibility. Here we examine the way in which the logic of computation and the network give rise to new forms of power that permeate computational societies. As we have seen in *2.3 Partial Perspectives* the production of representational systems affect, and exist as, political functions of various forms of authority and claims to authority. As the software and hardware of computation become increasingly hidden and embedded it necessary to understand the way in which computationally dominated societies function to express these political relations.

If we recognise that computation acts to create new forms of subjectivity, that is abstract subjects, that occupy and interact in digital spaces, it would seem that to understand their politics requires an investigation of the rules through which these spaces are constituted. Computation, as we have explored it, can be suggested as a system of representations of people and things, and a series of protocols, physical and abstract rules, which govern the interrelation between these representations. That people interact through these protocols for the variety of tasks and activities, relationships with objects and each other, and as forms of representing themselves, places specific emphasis on the ways in which these protocols mediate action within the representational domain.

Rather than the information/cognition focussed approaches, or the media/technological hardware focussed investigation discussed above these works form an archaeology of power. Bratton, for example, focuses on the geopolitical implication of global scale computing architectures which he refers to as "The Stack" (2015). As with the previous sections, Bratton explores the software implications of global computing composed of software subjects and enacted through the cybernetic systems of the network. However, he directs his focus towards the protocols, physical architectures and infrastructures that pervade the physical, political and electromagnetic spaces of the globe – in this sense he attempts to draw the areas of cybernetics, control, information and software together under the auspices of a changed geo (rather than individual) politics. Bratton identifies what he sees has a reorganisation of geopolitical space around the global computing megastructure. The, *"nomos* of the Cloud", Bratton notes is the break from a

Westphalian[27] concept of sovereignty and geo-political space, fragmented and reformed around the infrastructure and interfaces of the Stack. Here sovereignty and power reform around the switches that flip-flop open and closed allowing one bit of information through and annihilating the other (2015, 32-33). This protocol view is shared by Alexander Galloway:

> *Protocol's native landscape is the distributed network. Following Deleuze, I consider the distributed network to be an important diagram for our current social formation. Deleuze defines the diagram as "a map, a cartography that is coextensive with the whole social field". The distributed network is such a map, for it extends deeply into the social field of the new millennium.* (Galloway 2004)

For Galloway and Bratton, we can suggest that the systems diagrams of information control are considered actual. Rather than describing systems with diagrams, real space takes the form of the diagram itself.

These positions contain a common thread describing a reorganisation of societal functions through the technological rules of computer hardware and software superstructures. It is important to say, however, that these mediations do not instantly displace all existing mediations of, for example, culture, history, legal structures or physical barriers. It would be unwise to suggest a new technological teleology as an alternate transcendent narrative for the formation and structure of all relations. Rather it is worthwhile to examine the way in which these technological mediations exist and develop as a way of charting a progression towards a society inter-mediated by a new

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[27] The notion of Westphalian Sovereignty is the basis of international law in which each nation retains sovereign power over its territories. Developed as a part of a series of treaties signed in Osnabrück and Münster in 1648 to end a series of European wars the concept of Westphalian peace has remained at the centre of much of international relations to the present day. However, the notion has been challenged repeatedly throughout this period and many interventions by sovereign states in the affairs of other states have been justified through various means. A discussion of the basis of which can be found in *Sovereignty* by Hinsely (1986).

set of fields; technological, environmental, military, political, apolitical, electromagnetic and so on.

One such element of this mediation is through the protocols of exchange that control the information flow across the network. A system of algorithms and storage architectures act as the fundamental laws of existence within the domain of a globally networked computational society. These rules regulate access to computational spaces and computed bodies, control movement and geometry within computational fields and creating the limits and forms of existence for computational ontologies. The algorithmic and data structures of digital space appear as a metaphor of the fundamental forces of theoretical physics in their shaping of computational geometries and topologies, structuring the digital matter of computation as electromagnetic and gravitational forces structure the astral and subatomic geometries of the physical world. The agency of these forces permeates the networked structure of society, as with the fundamental forces of physics their presence is at times hidden or elusive and at times tangible and explicit.

The usefulness of this metaphor between the software forces of computation and the fundamental forces of nature, however, comes unstuck when we realise that the software forces are encoded laws that must be given to the computed world, rather than taken, or discovered, from it. These software forces are encoded through representational systems, the choices we make in their design, and the limits of their representational paradigm. These rules, Scott Lash argues, are a new form of structuring apparatus that sets them aside from the regulative and constitutive rules through which society has previously been structured. Lash argues that the software rules exist as a set of generative rules. He notes, '"Generative" rules are, as it were, virtuals that generate a whole variety of actuals. They are compressed and hidden and we do not encounter them in the way that we encounter constitutive and regulative rules' (2007, 71). For Lash then it is clear that the software forces of the digital space control the existence of the virtual and act outward to shape the "actual" in as much as they are shaped by it. They create the field of their operation by creating new modes of being. These rules exist as a form of power, deciding what flows and what is blocked, what can exist and what is deleted and even more importantly what shape existence can take.

It is possible to think of algorithmic decision-making as a form of sovereignty, or indeed a form of sovereignty making, a drawing of the line around what is inside and thus what remains out. This decision-making power mirrors in the algorithm the role of the sovereign leader in the political theory of Carl Schmitt. Schmitt's famous definition of sovereign power states that the sovereign is s/he who has the power to decide on that which cannot be determined within the rest of the body of legal regulation and general norms, and must therefore be decided as an exception to those norms. This power Schmitt notes, however, must not be limited in its understanding only to the state of the exception from which it derives but must be seen, 'to refer to a general concept in the theory of the state' (2005, 5-6). Thus it expresses itself at its limits in the monopoly of violence maintained by the state as the ultimate ontological power (Derrida 2002, 268).

This idea of ontological power in the physical domain is also reflected in the abstract through the structuring forces of software where access and existence converge within the representational forms of the network, the ontological biopower of the material world becoming an ontological power over representation within the abstract fields of computational society. The convergence of these two forms of ontological power, or ontological power in two domains – the physical and abstract – is discussed in more depth in *Chapter 4*. However, it is useful to think of it briefly here in its relationship to protocols. Ontological power in the physical domain can be thought of in terms of the power of the physical being, or the possibilities for being. In the computational domain, this definition also holds albeit for the computed (rather than physical) being, however, this is added to by the fact that the protocols of computational space also act to limit the way in which the computed entity can be represented as abstract and so the ontological possibilities in computational space are limited through the possibilities of representation. It is possible to suggest then that the protocols of the network enact the ontological power of the sovereign in computational space.

Aspect	**Hegemonic Age**	**Post-hegemonic Age**
Cultural studies	First Wave	Second Wave
Politics	Normativity	Factivity
	Counterfactuals	Facts
Rules	Constituative	Constituative
	Regulative	Regulative
		Generative
Organisation/Form	Epistemological	Ontological
	From without	From within (immanent)
	External organisation	Self-organisation
	Semiotics/Discourse	Being
	Cognitive judgements	Vitality
Culture/artefacts	Realm of value	Realm of fact
	Outside of profane everyday	Inside of profane everyday
Social Relations	Social bond	Communication
Mode of Legitimation	Legality	Performance
Cultural Logic	Reproduction	Invention

Empiricism	Positivism	Empiricism of the thing, of the event

Table 3.2 A table depicting Lash's power binary. (Beer 2009)

Lash suggests that software forces of algorithmic and computer architectural power, their generative rules and ontological character, constitute a reorganising of power structures that act as a break from what, drawing on Gramsci, he termed the age of hegemonic power (Lash 2007; Gramsci 2000). Lash calls this new form of power post-hegemonic power. Like Haraway, Lash identifies a number of changing characteristics that mark out this break, tabulated by Beer in *Table 3.2*. As with Haraway it is worthwhile listing some of the changes here that are most pertinent to this thesis. These are: Politics of normativity > Politics of facticity, Epistemological organisation (semiotics) > Ontological organisation (being), External organisation > immanent organisation, Social bond > Communications, Legal Legitimation > Performative legitimation, Logic of reproduction > Logic of invention and Positivist empiricism > Empiricism of the thing/event (an empiricism based in the convergence of the virtual and actual) (Lash 2007; Beer 2009). What can be seen in Lash's contention is that 'power through the algorithm' (Lash 2007, 71) is expressed with respect to a number of new conditions such as performativity and communication and that it is expressed from within and across the structure of the network rather than from above, or through traditional legal/military/state hierarchies. Across Lash's binaries can be seen the relationship of power to the optical nature of representation – power, communication and organisation become intertwined with existence within the abstract representational structures of computation technologies. It is possible to propose, that for Lash the fundamental features of this new form of power are visibility and representation within the matrices of global computation. The power of software forces as an immanent and ubiquitous structuring system could be seen as the feature that gives rise to the logic of invention that Lash proposes. Here the algorithm and the system architecture are the field in which invention takes place and as such create the conditions of possibility for any such invention.

The link between these forms of power and the expanded notion of computation that we have discussed in *Section 2.3.2* is made by Totaro and Ninno. They connect the logic of the algorithm back to the Enlightenment's logic of rationality and suggest that what Marx had identified in *Capital* (1976) was a mechanisation of human practice within the factory that followed the structure and logic of the algorithm. They say, 'it was the rise of a mentality oriented towards process formalization that facilitated the designing of mechanical equipment and their spread' (Totaro and Ninno 2014, 33-4). What Totaro and Ninno specifically identify within the early industrial stage, but also as a distinctive and important structural formation of algorithms is the importance of functional recursion. This recursion is, they say, the central operative element of all algorithms and follows the *zero function* and *projection function* which give rise to the initial conditions and initial process terms. They go on to note the importance of this recursion in algorithms with reference to Turing's vastly important computer science paper *On Computable Numbers, with an application to the Entscheidungsproblem* (1936). They note, 'Recursive functions and Turing machines are formalizations of the informal and intuitive notion of algorithm. It has been proved that these formalizations are equivalent, in the sense that if a number or a mathematical function is (effectively) computable with a Turing machine, then this number or function is recursive' (2014, 31). They conclude:

> *"…since the set of real numbers is 'larger' than that of natural numbers, there are real numbers (the majority) that are left out of this one-to-one correspondence with Turing machines. This means that there are real numbers that are not effectively computable and therefore not recursive (Minsky, 1967: 157–68). An immediate implication of this result is that we cannot fill the continuum of a*

> *numerical axis with effectively calculable real numbers (integers, rational numbers, and some irrational numbers). Turing machines, and therefore recursive functions, only allow us to operate within the 'discrete'. To reach conclusions within the 'continuum', we need to abandon effective calculation in favour of 'analytical' calculus."* (ibid, 31-2)

Totarro and Ninno's work therefore links the power of protocols back to the earlier discussions on partial perspectives and representational systems in *Chapter 2*. They highlight how algorithmic structures are operative only within a specific portion of total knowledge and with reference to the "discrete facts" that can be calculated within their recursive processes. In other words, the power of the algorithm operates with reference to that portion of knowledge that is performative within the software structure. As such this link bridges the thinking of the world as information in *Section 3.3,* to the politics of contemporary society.

The feature of contemporary power described by Lash as its immanence, relates to existing expressions of power in allowing or preventing access to the expanded computational reality, rather than the substructural way in which it organises society. For example, it is possible to think of the way in which the algorithmic orderings of Google's searches make visible or invisible the presence online of one entity or another. The algorithm thus displays ontological power over the representation in a way that spills out of the abstract to alter possibilities in the real. As suggested before, however, this move to Lash's "post-hegemonic order" does not mean that the basis of hegemony, that the many are subordinated by the few, has disappeared. Equally, the move to a post-hegemonic order does not mean that symbolic domination, legitimate power, or viable institutions no longer can or do exist. Rather the computational society signals a change in the way in which existing power relations are expressed. This change comes about not because they were overturned by the subordinated or because of their inability to generate consensus, but because of their obsolescence or inefficiency in the face of these new and immanent protocols of control.

In the political logic of networked societies, the efficiency of control through the network has made it the ultimate site for control. It is the basic structure of the multi-nodal network and the technological capabilities and properties of modern digital communications that give rise to this change. The speed of the telecommunication network and the processing power of the data centres that control data upon the network give rise to digital omnipresence and instant deployability. Data and resources can be routed to any physical location that is connected, and through its protocols to every computational space. Furthermore, the decentralised and multiply redundant network design ensures constant information flow through continuous recombination of information transport routes allowing data to be rerouted to avoid any blockages or obstructions placed in its path. In this way the expression of power over the abstracted software bodies becomes instant and ontological. This has been termed by Critical Art Ensemble as “Nomadic Power” (2000). For CAE, nomadic power expresses itself as a diffuse power field operated globally through the transport routes of the network;

> *Where once this model of power operated by the Scythians was limited by the physics of real geometric space, The Network’s speed now offers the nomadic forces of power recombinant omnipresence, an expression of power closely resembling the speed of annihilation Virillio expresses in the omnipresence of a nuclear ontological threat (2007).*

As with the cybernetic and software understandings of society artists have tried to engage with these changed power formations. Generally, this work has existed in response to power, rather than as a neutral exploration of its form and meaning. As such tactics have differed from those of symbolic action in favour of tactics and strategies of instrumental action within the developing matrices of power. This change of approach it can be suggested is necessitated by and reflects the change in the structure of power described above. In other words action is sited immanently within the structure of networked power. CAE describe the need for this change in a way that mirrors Lash's reorganisation. They describe action that is no longer aimed at the normative, the semiotic or the transcendent but that operates from within the reality of the power matrix;

> *Appropriating media gains nothing in undermining an authoritarian semiotic regime because no power base benefits from listening to an alternative message; however, appropriating profit through blocking information sends a clear message to any chosen capitalist institutions—for them, it may be cheaper to change policy than to defend militarily a semiotic regime under pressure.* (1996, 17)

This attempt to inject critique into the productive circuits of society has been carried out by CAE themselves through the use of public actions that were intended as instrumental rather than purely symbolic. Projects such as *International Campaign for Free Alcohol and Tobacco for the Unemployed* (1998), *Concerned Citizens of Kyoto* (2010) and *Keep Hope Alive Block Party* (2013) all attempted to redesignate public, or seemingly public, spaces by injecting the possibilities of other circuits of consumption into them. Admittedly though, CAE found aspects of this approach limited in its effectiveness (2001) and these limitation collapses the works back towards acts operating in the realm of spectacle. Similarly work by artists such as Cildo Meireles and collective n55 have attempted to directly inject their works into the performative circuits of society. Meireles' *Insertions into Ideological Circuits* (1969) recognised in some part the increasing importance of meta-information as an ideological component of contemporary society. By adding messages to reused Coca-Cola bottles and bank notes that went into circulation, Meireles was able to insert an additional level of information into an existing infrastructural circuit of information transfer. As such his critique sat upon the network but without disrupting its flows, his messages were a meta-informational addition to the circuits' embedded messages. Electronic Disturbance Theatre (EDT) are another collective who have engaged in such attempts at instrumental interventions in the productive circuits of computerised societies. However, for EDT these interventions exist within the digital domain. The project *FloodNet* (1998) was a distributed HTML and JAVA applet designed to create a distributed denial of service (DDOS) attack on the websites and web servers of target organisations such as those of the Mexican and American government defence departments and the World Trade Organisation. The project created what EDT saw as an act of electronic civil disobedience similar to the idea of peaceful protest within physical space but located within the channels of the computer network. Carried out in the late nineteen nineties, FloodNet and the reaction to it highlighted an increasing convergence in the understanding of abstract and physical property that will be discuss further later within this thesis. Ultimately, however, FloodNet was quickly deemed ineffective as the web services of it targets used increasingly sophisticated methods to prevent such tactics of obstruction to their services – an example of the recombinant and nomadic structure of power highlighted by CAE.

As we have seen with the work of artists throughout this chapter it is possible to suggest that these artistic critiques of power insufficiently account for the role of abstraction in the expression of contemporary power. Whilst their attempt to inject critique into the circuits through which power flows, their attempts generally do so within the domain of the physical entity rather than in the domain of the abstract. Floodnet, perhaps is arguably most successful in understanding this informatics nature of power, but its instrumental critique was quickly subsumed by the nomadic and recombinant nature of the power against which it was pitched. Representation it can be suggested sits below the subject of these critiques, however, it can be suggested that given that the algorithmic power of the protocol acts upon representations then understanding how these representations are formed and processed must become an element of this critique.

3.5 Conclusion – The Art of Drawing Disappearing Maps

In this section we have seen the work of artists and theorists that have tried to examine the changes in society precipitated by the new technologies through which they have seen it being increasingly constituted. Their approaches have been varied, representing the varied facets of technological developments and various aspects that have at times seemed most prominent and most constitutive of the changes that have occurred. The proposals in this chapter combine and overlap to give us a view of the world divided as it may or may not be into spheres of politics, networks, societies, ecologies, actors, subjects or machines, in which the software, hardware and protocols of the global computer infrastructure act as defining characteristics. In other words, this chapter gathers together investigations in which the computer forms the basis of the position in which we find ourselves.

It is possible to propose, however, that although these analyses are insightful and useful they ignore the structural basis on which this computation sits – the manipulation of abstracted representations. This thesis does not intend in any way to supplant or replace these other works, but rather to accompany them in gaining a better way of understanding the role of computation in contemporary and future societies. As such this thesis suggests that the essential political and philosophical implication of the global computer architecture stems from its structure as a representational system that is in an increasing and continuous process of modelling the world.

Those inquiries that have focussed on the hardware and cybernetics systems of computation generally represent some of the early enquiries into computation and thus they reflect a preponderance towards the material or spatial construction of the network, composed of domineering physical machines and systems on which early computational technologies operated. In addition, much of the early systems theory and cybernetic art practices reflected an optimism about the potential of computers as idealised processors of information. The work thus was often focussed on how these networked systems could act as a structuring matrix for a society that was built around them. This systems theory of society used the newly available languages and diagrams of computer network organisation in an attempt to understand a society in which information flow would become the primary dynamic element and unit of operation. The fundamental difficulty presented by this approach was the inability to properly account for the difference between a model and that which it represented. As was seen in the discussion of cybernetics and Systems Art this difficulty presented itself when attempts to fully account for the complexity of a system would render a model illegible or remove from it the ability to function as a defined form of communication with a defined relationship between its input and output elements. At the same time the attempt to render a diagram as legible, as seen in the work of the early Systems Art or in the cybernetic models proposed by systems theorists, often required the black boxing of complex elements that meant the model was incapable of fully accounting for the complexity and subjectivity of the elements contained within.

This difficulty, which remains unresolved despite attempts to resolve it through vastly larger and more complex models, seems to stem from the inability of a model to account completely for the complexities of a system without becoming the system itself. In other words, for a model to completely describe a system without the aggregation or negation of certain differences the model would in the end be the same size as the system itself. The difficulty presented by this problem can be traced from to the issues of incompleteness and objectivity discussed in *Section 2.2*, in which Gödel described the impossibility of a formal system ever being fully described without reference to some greater and larger system. This difficulty presents itself with ever greater urgency as the development of global computation expands to ever-new areas of existence.

On the other hand a focus on the software aspects of computing technology has perhaps achieved a richer theoretical ground. Hayles, Haraway, Castells and Lash for example appear to both accept and critique the information centric reorganisation of society. Their various scholarships point towards a society in which information sits as software upon a variety of substrates whether organic and machine. These approaches have suggested the possibility of restructuring society at an instrumental level, altering the subject and the expression of power and bringing with it features of digital mutability, replication and omnipresence. This restructuring has the potential to redraw the boundaries of the overlapping spheres of the individual, political, social, environmental, animal, machine and so on, such that they may regenerate or dissolve entirely. Whilst these discussions are hugely insightful at an instrumental operational level in understanding a politics of where we are now, and where we might be going, more attention needs to be paid the underlying requirements of computer architectures. Namely, that computers require that the codes through which society, as these theorists propose it, might be formed must be shared by all that use them. As such it can be suggested that the ideas of constantly mutable codes reorganised subjectively by individual actors is inconsistent with the computation's function. Perhaps Lash and Haraway come closest in the dichotomies presented above wherein they propose a move from reproduction to replication, from epistemology to ontology and from mind to artificial intelligence. What they recognise in these is a convergence between the abstract representation and the physical entity. However, they do not go as far as to say that for these two to converge the being must become compatible within the representational structures that define the computing machine. They draw out a restructuring relationship but fail to develop this sufficiently to suggest the direction in which this restructuring will ultimately lead. If the world is to be formed of codes, the question as to who these codes are chosen for and by remains to be answered. And so these approaches, it can be suggested, fail to fully account for the fact that for the world to exist as codes these codes must exist within some ontological frame that defines their rules, their encoding and decoding relationships and their relationship to the physical entities to which they pertain in physical space. As we have seen in the last section and in the previous chapter, the codes of digital space are not taken from the physical world, but given to it in the construction of the representations from which it is composed and in the protocols that define the relationships between these representations.

What this thesis proposes and what we will go on to explore in more depth in the following sections is that beneath the software, hardware layers and their networked protocols is the process of representation. Despite the richness of the varied approaches by artists and theorists, there is a need to better understand the way in which computational representation acts as a way to communicate the physical world. What we will see is that understanding this, and the changes that it brings about is not only critical for understanding where technology has brought us now, but also where it will bring us in the future. What this chapter has shown is by drawing art practice and theory together based on thematic focus rather than disciplinary boundary – we can see that there is a need for a focus that accounts for the importance of abstract representation as a key element of computation. In order to do so, we must move from an analysis of the theory and practice of others and examine how abstract representation is currently acting to restructure society.

4 The Convergence of Map and Territory

"In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it." – Jorge Luis Borges

4.1 Introduction

This thesis proposes that the logic of computation organises society around abstract representations. This chapter examines examples of this reorganisation and explores mechanisms by which this process is reproduced in contemporary society. It does so by examining examples of this trend evident today and goes on to suggest a mechanism by which computation furthers an understanding of the world through shared abstract definitions. In *Chapter 2 Representation: A Critical Background* we discussed the idea of computational systems as those that organise the world through a system of abstract representations, systems that capture the world through the prosthetic senses of measurement and that carry out transformations on those representations in order to predict, analyse and control the actions of those systems of which they are a part. In *Chapter 3 On the Structure of Posthuman Technosocieties* we saw how artists and theorists tried to come to terms with a society that is increasingly constituted through computing technologies. Despite these varied and useful approaches insufficient attention is being paid to the abstract representational structures on which computation is based. As the role and reach of computation expands in society and new forms of sociality and understanding become possible, so too computation changes existing ways of knowing, acting and relating to ourselves and others. In this chapter we will explore the role of abstract representation in relation to these changes and will show how increasingly the understanding of the world is based upon abstract representations. By examining the underlying mechanisms of representation and communication that are fundamental to this understanding of computation it will also be possible to examine the mechanisms by which these changes take place and by which they are reproduced and multiplied.

The first part of this chapter, *4.2 The Convergence of Representation and Being*, identifies the trend which is the central focus of this thesis, i.e. the convergence of being, and of our understanding of being – that quality of existence shared by humans and non-humans alike in their place within existence - with representation within the abstract structures of technology. It is necessary, when talking about a world that is not abstract, not to limit our discussions to abstraction or theory, but to examine how this convergence is already happening and in many domains is already quite advanced. By looking at real examples what we can see is that increasingly computational abstractions are becoming the primary surfaces for our interaction with the material world, with each other and with ourselves. This trend is examined in a number of varied contexts as a way of demonstrating the wide-ranging changes that are precipitated by the representational structure of computation. In doing so the chapter is not an exhaustive list of all examples of this convergence. Instead, it is a way of demonstrating evidence for this convergence across a number of varied but related fields in order to show how ways of being are transformed by the representational logic of computation.

The section starts off with a detailed look at one particular computational technology – universal time – that predates modern computing machines but which demonstrates the way in which the abstract representations of computational logic become embedded in our understanding of phenomena. *4.2.1 The Universal Clock* examines how time as an abstract computational technology forms part of a wider convergence between the understanding of time, time as experience and a universal external clock. Having examined time *4.2.2 The Representational Economy* will examine the increasing provenance of abstract representation across the fields of money, work and labour. *4.2.3 The Abstracted Being* will go on to examine how the representational structures of computation act to alter the relationship between the individual and society and the individual and themselves. By looking at these varied examples the chapter will suggest that a wide variety of changes in society can be considered as being manifestations of the same trend, namely the convergence between representation and being within the structure of global computation.

In the second part of the chapter, *4.3 A Reciprocal Engine of Actualisation*, we will discuss the mechanisms that drive the convergence identified in the first section. Whilst the practice part of this thesis will try to find ways to explore what happens when we relate to the world increasingly through the representational structures of computational systems it is necessary also to try and identify some traits of representation and of computation that lead to the changes identified within this chapter. In doing so it will be possible to see how the abstract representations of computation give rise to an increasingly computational construction of society. In order to undertake this examination it is necessary to examine the abstract representation of computation in the wider contexts of representation, perception, and in relation to other forms of knowledge and knowing.

4.3.1 Representational Knowing in the Human and the Machine examines the way in which the representational structures of computation differ from other forms of representation, such as language, in their relation to encoding and decoding between the real and abstract domains. In particular the section will examine how computational representation requires a strictly encoded representational ontology to be shared between entities, be they human or machine, in order that the representational system can function as a form of communication. As such this section describes how the central requirement of a global system of computation is a universal ontology with which to describe phenomena.

Having suggested the requirements of global computational representation, *4.3.2 Perception, Affect and Memory* examines the ways in which the structures of representational systems act to alter our understanding of phenomena. In particular the section draws heavily on the work of Henri Bergson in order to suggest a mechanism by which the representational structures of computation become embedded in our understanding of the world. The section goes on to suggest that as a result types of knowledge that are consistent with the representational will predominate within a global system of computation, whilst those forms of knowledge which are not easily encoded within representational structures will diminish.

Finally, *4.3.3 The Information Theory of Contemporary Society*, examines how a universal system of ontology with which to describe the world requires a convergence of individual subjective knowledges. The section draws on the information theory developed by Claude Shannon to suggest that in order to maintain its function as a system of communication a global system of representation requires that individual subjective knowledges converge towards a universal understanding of phenomena. In doing so there is a link back to earlier discussions on partial perspective and knowledge authority to highlight the need to find ways to question which forms of knowledge become dominant in a universal mapping of the world.

4.2 The Convergence of Representation and Being

> *The Black Stack, then, is to the Stack what the shadow of the future is to the form of the present. The Black Stack is less the anarchist stack, or the death-metal stack, or the utterly opaque stack, than the computational totality-to-come, defined at this moment by what it is not, by the empty content fields of its framework, and by its dire inevitability. – Benjamin Bratton*

4.2.1 The Universal Clock

So far computing technologies have been identified as technologies that map the world through abstracted representational structures. Computers are technologies that encode the physical into abstraction and that manipulate the world through algorithmic and computational logic. However, in our expanded definition of computation we have seen how human and machine processing can also be considered as computational. Taken in isolation these observations may initially seem mundane, that computers relate to the world through a computational logic seems almost self-explanatory. What this section will identify is that the representational logic of computation acts outwardly to restructure the understanding of the world in which it exists and that this restructuring produces a convergence of representation and of being, of the phenomena and the abstract. As such 'being' – the phenomenon in the real domain increasingly becomes constituted through the optical strategy of "being represented" within an abstract structure of computation, and so the representation increasingly comes to be conflated with phenomena itself.

The first technology that we will discuss – time – is one that predates any modern sense of computation. However, time is a computational structure within the expanded definition through which we have examined it. People have measured time, it can safely be assumed, in some shape or form relative to varying needs since the beginning of humanity[28]. The rise of the sun, its zenith and its fall has marked the diurnal cycle of the earth around its axis. The change in this pattern from winter solstice through equinox to summer solstice and back to equinox has marked the annual trip of the earth around its closest star. For much of humanity's history, and even today for many people and in

[28] It is debated, in particular in primatology amongst other zoological sciences, that animals in various ways also measure time (Roberts 2002).

many situations, this system of measurement has been a sufficient tool for marking time – as a framework for the organisation of activities and as a method for marking the change in or duration of various processes. Beyond the external clock of the sun remote and local techniques were used to divide these cycles further, water clocks, hour glasses, candles and other techniques allowed duration to be marked and activities coordinated in shorter intervals or in the absence of the sun's light.

As people moved in great numbers to cities during Britain's industrial revolution, and as trains ferried them between and amongst these cities, from their homes and to their workplaces, an agreed system of time was required such that large groups of people could participate in, coordinate and measure a wide range or disparate activities. It would seem obvious then, that "knowing the time" would become a central requirement for modern living. However, on closer inspection we see that knowing the time, i.e. the position of a person on the surface of the earth relative to the earth's rotation about its axis itself is unimportant, instead it is knowing and conforming to a point within an agreed system of time that matters. "Time" comes to be represented by the clock standard time a universal abstraction that approximates the earth's rotation to a resolution of twenty-four hours divided by wavering boundaries of political borders. The earliest standardisation of time was just such a practical application and was implemented across Great Britain by British Railways in 1847. From this point on, local time across Great Britain, as in time of day, was no longer connected to the astrological time of day, i.e. midday being the point of the sun's zenith, but rather controlled by the time stated at Greenwich Observatory. With the advent of the 1884 Meridian Conference in Washington D.C, the time at Greenwich Observatory became the universal standard around the globe giving rise to Greenwich Mean Time (GMT), and later Coordinated Universal Time (UTC), the primary standard by which time and timekeeping are regulated globally today.

This standardisation of time, thus far, gives little indication that its importance extends beyond the organisation of transport systems and coordination of activities. However, it is possible to suggest that time has become one of the dominant structuring architectures of contemporary society. Mumford, in his wide-ranging discussion of technics suggests this point, stating, ‘The clock, not the steam-engine, is the key-machine of the modern industrial age. For every phase of its development the clock is both the outstanding fact and the typical symbol of the machine: even today no other machine is so ubiquitous’ (1934, 14). Mumford’s proposition resonates with the later work of Totaro and Ninno, which we saw in *Section 3.4*, in suggesting that the logic of computation is structured around thinking through abstract representations and their structure rather than related to the existence of strictly computing machines. As such the existence of computational logic and the existence of computing machines act together to increasingly create the possibilities for each other, a point which will be explored in more detail in *Section 4.3*. Mumford continues that, ‘In its relationship to determinable quantities of energy, to standardization, to automatic action, and finally to its own special product, accurate timing, the clock has been the foremost machine in modern technics: and at each period it has remained in the lead: it marks a perfection toward which other machines aspire’ (1934, 15). Mumford’s suggestion, made in the early twentieth century, it can be argued still holds true today. At the forefront of advanced computation and networking technologies the clock, and the ability to perform operations in limited clock time is the key criterion of performance. Meanwhile at the forefront of the development of the practices and process of measurement, which we explored earlier, the measurement of time sits as the fundamental unit from which the definition of all other physical units of the SI systems are defined[29] (Consultative Committees of the CIPM 2017).

More important in the context of this research than the clock's ubiquity, is the extent to which it is representative of the computational mode of organisation structured around the abstract representation of time. A universal standardised time is in fact a form of network architecture. It is an invisible linkage that structures the action of disparate nodes across real and abstract space. “Knowing the time” is not important – but rather it is coordinating a shared understanding of the time that becomes critical. This reorganisation of understanding towards the universal is central to functioning of representation (as we will see throughout this chapter and as will be explored in greater detail in, *Section 4.3*). At the same time, it links back to the mercantile need for coordination of phenomena across distance that was discussed in *Chapter 2*. In this way the coordination required for a functional abstract representation of time is inseparable from the requirement that individual perception of time becomes reconceived through the shared representation. At a practical level this structuring is easy to see across almost all levels of society, in the work place the company clock requires employee's presence between certain hours, and certain tasks must be achieved before particular deadlines, whilst the universal clock determines whether a hotel booking or financial transaction was carried out before or after a competing transaction. This structuring extends out of the work place too, where an allotted time is granted for eating, bookings are made for evening meals and the bars close to allow a designated number of hours before the working day restarts at the same time one day later in the calendar's progression.

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[29] The SI system of units which includes the second, metre, kilogram, ampere, candela, kelvin and mole forms the basis of modern scientific measurement and these units form the basis from which all other physical measurements are derived.

Beyond the ordering of tasks in the sequence of universal clock time, universal time also imbues value on processes and practices. The link between clock time and value production is central to the industrial mode of capitalist production (Thompson 1967). The production of new material and immaterial value is shaped around the hands of the clock. How much time can be provided and how much time can be spent in the production of such values forms the basis of monetary value of many services. Meanwhile disparate value is placed on the time of various activities and those of various workers – time thus acts as a hierarchal structuring network rather than simply a coordinating one. As such new forms of knowledge production and practice become 'entimed' (Hörning *et al* 1999, 294), their value being inherently fixed to the time they take to produce or consume. Time, measured to the second, the millisecond and the nanosecond becomes an accountable and exchangeable quantity.

Time, for most humans, remains linked to the observance of astronomical movements of days and years, and to the duration of human lives, thus there remains a limit on the availability of total time. Time unlike other immaterial commodities of value (discussed further in *Section 4.2.3*) cannot be generated infinitely and this limit creates a scarcity. The scarcity of the total thus requires smaller and smaller division of time in order to create increasing measures of value in the productive logic of capitalist expansion (Solnit 2003, 15). Whilst more time, in the astronomical sense, cannot be created more abstract units of time can. This decrease in size, the measurement of time at quantum resolution, brings with it an increase in speed that is central to what has been termed capitalism's "accelerationism" (Noys 2010, 5). As time is measured in ever smaller subdivisions so too increases the potential for creating value within subdivided limits of scarcity that a fixed conception of time, anchored in the world of human biology and perception allows. This acceleration and subdivision move time as abstract further away from the perception of time in human perceivable and experienced scales towards the prosthetic senses of technical apparatus.

Clock time, represented as a unilinear subdivided series of instances can be suggested as changing the way in which we relate to the world, by universalising experience as a form of representation within an external abstract structure. In this way the clock is a computational technology, an abstract representation of the form we have described. The unilinearity and regularity of the clock's abstraction places clock time at odds with both our individual perception of time (Allan 1979) and with many traditional conceptions of time that were central to many of the main religious and pagan traditions outside of the Judeo-Christian tradition. In many such traditions time was viewed with varied topologies and trajectories including circular, spiral and helical. Time, however, throughout other pre-computing historical conceptions had also been viewed as unilinear, St. Augustine, whose early conception is central to western Judaeo-Christian, thought of time as mutable, transitory and irreversible (Hausheer 1937). Indeed, many traditions that use non-linear trajectories of time also allow for an element of linearity, the spiral, for example, includes a linear function describing the decreasing radius towards or away from the centre and the helix along its axis. This linearity is evidenced through the recording of history on a linear scale inside of the non-linear timelines of mythologies, astronomy or natural cycles.

Regardless of the particular conception, time flowed in some form that was used to make meaning and to structure activity as human action. With universal clock time the agreed abstract measure becomes the primary structuring apparatus. Mumford sums up the changed relationship between time and the universal clock:

> *The clock is a piece of power-machinery whose "product" is seconds and minutes: by its essential nature it dissociated time from human events and helped create the belief in an independent world of mathematically measurable*

> *sequences: the special world of science. There is relatively little foundation for this belief in common human experience: throughout the year the days are of uneven duration, and not merely does the relation between day and night steadily change, but a slight journey from East to West alters astronomical time by a certain number of minutes. In terms of the human organism itself, mechanical time is even more foreign: while human life has regularities of its own, the beat of the pulse, the breathing of the lungs, these change from hour to hour with mood and action, and in the longer span of day, time is measured not by the calendar but by the events that occupy it.* (1934, 15)

What is different in the technological time of the clock is the introduction of a universal unit of measure, time no longer as perception – or chronoception - but as an explicit framework external to the individual.

The relationship of time to perception is deeply bound up with theories of affect and sensation, memory and identity (and in theoretical physics with theories of space). Whilst Locke (2012) and Kant (1922), amongst others, required transcendence from the self to allow a universal understanding of time, Husserl (1991) and later phenomenologists such as Merleau-Ponty (2004) position time's passage as existence only in the immediate sense perception, on the other hand Heidegger's (1996) *Dasein* is as part of a world that includes time, neither inside of or without the individual. In each case, time is perceived internally as experience. With universal clock time the locus of this experience is relocated to an external and objective measurement system. This movement alters and speeds up our perception of time itself (McLoughlin 2012) (Solnit 2003). Time perception as secondary to clock time in this way continually anchors our perception to the universal abstract representation and away from the subjective experience. This changed perception challenges the notion of a universal nature that is "discovered" by the clock –

a realist measurement interpretation of an unchanging nature – instead it can be suggested that the clock produces the concept of time as a linear and steady process. This altered hierarchy between representation and perception is one example of the convergence between being and representation the mechanism for which we will examine in *Section 4.3*, however, before doing so it is necessary to look at other examples of the way that our understanding of experience is being reshaped through the abstract representations of computation.

4.2.2 The Representational Economy

Whilst the representational logic of computational machines enables subdivision of time into infinitesimal but discrete blocks as a way of multiplying value within a capitalist productive logic, for pure capital – money - there is no such upper limit. Money, like time, is not a new technology and although its existence far precedes the dominance of the computational logic with which this thesis is concerned money is in essence a measuring technology. It is an abstracted method for representing some value through a numerical and exchangeable framework – and so like time money can be seen as an early form of computation. The early use of money as an exchange commodity was mostly related to local concerns, and thousands of individual systems of exchange or ledger keeping existed within or between communities to keep track of goods or services exchanged. With the Lydians (Horesh and Kim 2011) came the use of universal commodities such as silver and gold that allowed fungible trade more easily across communities with disparate needs and resources. By the time the Song dynasty produced the first paper notes (Horesh 2012), money had become predominantly representative with centralised holders of wealth issuing notes of credit whilst maintaining control over the commodities they represented. In the latter half of the last millennium the adoption of the gold standard, an exchangeable gold quantity for government issued notes, and the setting up of national banks that issued legal currencies and that allowed private wealth holders to fund the finances of sovereign nations, money became a dominant exchange network that transcended borders and allowed value to be exchanged from one country to the next. In this way, like universal standard time and the other systems of abstraction discussed in *Section 2.2.1*, money acts as a network architecture that linked the value of labour and of resources across geographic and economic nodes.

Money as a representative value network at the time of the gold standard was subject to the protocols of exchange rate and to the total commodity stability of gold, limited in its duplicability and extraction. By 1971, when the United States abandoned the gold standard (Weatherford 1997, 181), following most of Europe since the nineteen thirties, the world moved from an era of representative money to one which may be considered as representational money. Money became as Weatherford notes (borrowing from the 1888 science fiction novel *Looking Backward* (Bellamy 2007)), ‘an algebraical symbol for comparing the values of products with one another’[30]. The advent of representational money, money abstracted away from any limiting physical commodity but constrained only by its issuance, brought a boom of “money markets” and an explosion in the total quantity of money in circulation. Financial trading markets created new financial products that were backed only through complex mathematical and probabilistic relationships to either labour or commodity such that money became a “universal abstraction” (Hart 2009, 101) through which immaterial and material exchange can be represented. Hart, who describes representational money as a universal abstraction, positions it primarily

[30] For a useful description of the history of money in the later half of the last millennium *The History of Money* by Weatherford (1997) covers many of the changes that are covered in briefest detail here. Interestingly Weatherford’s discussion of paper money does not include early discussions of its use in China and his history in general is focused on European and American developments.

as a communications technology. This he describes as more reliable than language, a conclusion that can only be drawn from its quantitative structure (ibid.). This view of money as a network exchange protocol whose value is contained only in its representation thus places it also as a productive technology that brings the world into existence as a series of subdivided entities quantifiable through their relation to representational value.

The abstraction of money away from a commodity or sovereign *fiat* backed exchange mechanism to a purely representational abstract thus produces a number of effects. For example, the requirement for centralised power to either manage the commodity itself, or to guarantee through legal or instrumental authority and power the value of the exchange medium is replaced by the database or representational account. This indifference to centralised power creates the possibility of new sorts of representational currency, such as “virtual” and crypto currencies like Bitcoin and Ether[31]. These allow money to be issued without any theoretical limit, but also draw their authority from the facticity of the ledger of account. In other words, the representation of account becomes the fact itself without recourse to an external value. In doing so authority becomes immanent to the abstract structure of representation, a feature described by Lessig as, ‘code is law’, in other words that the representation is the primary authority, as opposed to pre-existing models discussed in *Section 2.3.2* such as the authority of the sovereign. It is noteworthy however that whilst these features represent a rebalancing of power between representation and being it would be premature to suggest this process is complete - O’Dwyer notes in *Code != Law* that when the algorithmic systems of finance malfunction recourse to the dominance of legal, institutional or state power can still occur.

[31] Bitcoin and Ether are two of the dominant cryptocurrencies amongst thousands of other “coins” in virtual circulation on the global computer network. Each is built on different versions of blockchain technology – a form of distributed ledger in which transactions are verified by all users (nodes consisting of computer and/or human users) of the ledger rather than a central issuing authority.

As noted in *Section 3.4* the increasing prevalence of representational power does not immediately replace existing structures of power.

In addition to the separation of money from material value, representational money also becomes delinked from labour, or at least human labour. Digital currencies are produced agnostic to the source of the digital processes by which they are produced unaware of the presence, if any, of human labour involved. Computational financial markets and cryptocurrencies alike allow for the possibility of money generated by algorithms – such as the automated and high frequency trading algorithms (Kaya 2016) or algorithmic "mining"[32] (Ahamad *et al* 2013, 44-45) of cryptocurrencies. Thus, financial value is increasingly created without the need for human labour and without the limitations of human time. Human labour, material value and algorithmic process become equalised within the representational system of financial account. It is possible to propose then that the abstract representation of money gives rise to a convergence between the ideas of human value – that is the value placed on goods and services as required/desired by individuals – and the abstract value of account, contained within the ledger of representational currencies. It is possible also to suggest that human labour becomes one of many sites of production within the wider field of economic flows, mirroring the descriptions of Hayles' cognisphere or Bratton's stack from *Chapter 3*.

Representational money and representational time coexist and become intertwined as part of a larger computational representational economic system that forms an increasingly large part of the overall system of economic production and division. As with measured time, and in fact in concert with it, money also acts not only as a

[32] Mining is the process by which blockchain transactions are verified by other nodes on the blockchain - in most blockchain technologies the process of verification produces new coins for the nodes that verified each transaction.

coordinating network but also as a hierarchal ordering system. Delinked from labour or material accumulation representational money becomes an abstraction of the social relations between individuals and others, and between individuals and wider governmental and social structures. When money becomes representational so too these relationships, hierarchies based on immaterial value, become enforced with reference to the computational account. This is both a movement of disappearance and solidification. At one end forms of social hierarchy that have always been made concrete by physical accumulation's existence and share, are dissipated into pure information, no longer bound to physical resources. At the same time this disappearance makes more concrete the fact that money acts only as a structuring of social relations that must be enforced by latent power – of law, of the state and of violence. In becoming informational it can be suggested that money's value rests more wholly on the structures of power with which it is enforced. Meanwhile, its form and practice – in data structures of the computer network – allow this structuring network to be traced more completely between the digital entities to who it is ascribed – as such the representation becomes the form of social order itself. As with the example above highlighted by O'Dwyer at present these forms of order are maintained with recourse to external – non-representational – forms of power. However, as visibility and access to the networked technologies of computational societies forms an increasing part of economic existence the control of the ontological power of access to the network (that was discussed in *Section 3.4*) may appear to increasingly enforce ontological power through the algorithm.

Within the context of an increasing representational economy, so too labour increasingly becomes reshaped towards the production of immaterial commodities and towards the production of representations (Hardt and Negri 2004)(Lazzarato 1996)(Gill and Pratt 2008). Immaterial labour can be thought of in terms of the production of informational and communicative commodities (Lazzarato 1996). Whilst immaterial labour is not new and has existed mainly within the services and cultural sectors, computing technologies tend towards the production of new types of immaterial labour, that is, the production of representations. If we consider immaterial labour, as above, as the production of communicative and informational commodities, whether that be the good or ill feeling towards a product or the provision of care in a therapeutic environment or as the production of representational value, what we see is an increasing trend toward the computerisation of this production. This computerisation is not limited to the medium of delivery of immaterial labour practices, e.g. video sharing, digital marketing, etc. but extends to the development of automated process for the production of affects and the attempt to map the production and reception of affects within algorithmic structures. This attempt to represent affective or contextual value is evident in areas of research such as sentiment analysis – “the computational treatment of opinion, sentiment, and subjectivity”(Pang and Lee 2006, i), the tracking of emoticons as emotion indicators across social networking platforms (Vashisht and Thakur 2014)(Pak and Paroubek, n.d.), the extraction of emotional content from speech patterns (Cogito Health Inc. 2014) or the production of software and robotic care assistants that attempt to provide both material and immaterial services to clients (DeVault et al. 2014) (Kolling et al. 2013). Each of the cases above, along with many other emergent technologies, attempt to model and reproduce computationally the production of emotional and affective aspects of immaterial labour within the representational structures of computing technologies. As we will discuss further in *Section 4.3.1*, however, is that this mapping of affects and emotions as universal variables within the network points towards the limits of representational systems themselves.

Immaterial labour also extends beyond the production of affects experienced within the material world towards the production of what may be considered abstract immaterial labour. In other words, towards the production of immaterial products that produce affects directly on abstracted representations as opposed to abstracted goods which produce and direct affect in the real domain. Abstract goods that exist within the economies of online games and social spaces such as *Second Life*[33] and *Cyword*[34] (Hamari and Lehdonvirta 2010)(Hamari and Keronen 2016) easily describe examples of this production. However paid access to professional and personal networks such as *LinkedIn*[35] or *Match.com*[36] can also be seen as the purchase of abstract goods that allow a user's digital identity access to other digital identities. Whilst tools for generating value such as trading algorithms or tools for hacking or altering that data of others can be thought of in similar terms. In the former cases highlighted here we can see the way in which the abstract representation - the avatar, profile or abstract entity - influences or controls the possibilities and opportunities for the real bodies to which they are linked. Thus, the abstracted social orderings of the representational domain come to be expressed in the physical domain.

One aspect of immaterial production that has been much highlighted by cultural and economic theorists is the increasing level of precarity amongst workers in the informational economy in particular amongst the producers of immaterial commodities. Much of this research has focussed on the reorganisation of the labour market towards the use of workers as dynamic resources and the associated requirement for nomadic or remote workers (Gill and Pratt 2008)(Vallas 2015) (de Peuter 2011) (Neilson and

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[33] Second life is an online virtual world developed by Linden Lab in San Francisco. Second life is intended as an open virtual world in which users are represented as avatars. Second life has an internal economy in Linden Dollars that are linked to the real economy through purchase in USD. Second Life allows a high level of customization and exchange of virtual goods.

[34] Cyworld is a South Korean social networking site in which users communicate using avatars in "mini rooms" that can be customised and decorated with exchangeable virtual goods.

[35] LinkedIn is a social networking site aimed primarily at business users and those looking to gain employment, sales and business contacts. Through a paid premium subscription service users can gain increased access to data about other users' actions and increased visibility in search results.

[36] Match.com is one of the world's largest dating sites. Match operates a premium subscription model in which paid users are given increased access to other users' profiles, to statistics about their own profile and to ways in which to contact users.

Rossiter 2008) (Pedaci 2010) (Brophy 2008) (Hardt and Negri 2004) (Bauman 2000). It is also possible, however, to see the reorganisation of labour as mirroring the Dynamic Resource Allocation or Multi-Agent Resource Allocation algorithms of computer networks. Here workers become mathematical functions that produce different inputs and outputs. In the computationally structured production process their utilisation is governed through the logic of performance and optimisation carried out upon the production process as abstract model. In this way workers become representational, - abstract entities or classes, their embodied skills and experiences become metadata within a computer readable matrix. As for other forms of algorithmic production the process in which immaterial commodities are produced are agnostic to the means of their production – be they human, machine or from some expanded human-machine assemblage.

Beyond the specific subjects of time and money, we can see that in the representational economy that the structure and organisation of society is increasingly shaped around the production and transfer of abstract representations. It is possible to suggest that as society becomes increasingly structured around communications technology based on the transmission of abstract representations so too the economic sphere becomes increasingly divided into abstracted, transmissible entities. In fact, given the history of measurement that we surveyed in *Section 2.2.1* it is possible to suggest that the division of the world into measurable and transmissible abstractions is one of the main forces that has driven the logic of computation from its earliest forms in standardised measurement to the advanced forms of communicative capitalism that we see developing today.

4.2.3 The Abstracted Being

> *Consider the following scenario: A person (P) walks into a bank with the idea of securing a loan. According to the dramaturgical structure of this situation, the person is required to present h/erself as a responsible and trustworthy loan applicant. Being a good performer, and comfortable with this situation, P has costumed h/erself well by wearing clothing and jewelry that indicate economic comfort. P follows the application procedures well, and uses good blocking techniques with appropriate handshakes, standing and sitting as socially expected, and so on. In addition, P has prepared and memorized a well-written script that fully explains h/er need for the loan, as well as h/er ability to repay it. As careful as P is to conform to the codes of the situation, it quickly becomes apparent that h/er performance in itself is not sufficient to secure the loan. All that P has accomplished by the performance is to successfully convince the loan officer to interview h/er electronic double. The loan officer calls up h/er credit history on the computer. It is this body, a body of data, that now controls the stage. It is, in fact, the only body which interests the loan officer. P's electronic double reveals that s/he has been late on credit payments in the past, and that she has been in a credit dispute with another bank. The loan is denied; end of performance.* (Critical Art Ensemble 2000, 58-9)

Within the representational economy the individual has come to be represented increasingly by their abstracted double. This abstract entity variously exists as part of a super-individual assemblage of the real and abstract entities from which the person is formed. The individual's physical labour or embodied knowledge increasingly forms only a part of this assemblage that includes the meta-data of their economic and social features stored as abstract properties. This super-individual assemblage exists as a combination of an individual and a infra-individual abstraction (Rouvroy 2015), where, as was seen in *Section 2.2.2* the sub-individual abstraction exists as a subtraction of the features of the individual based on the requirements of particular schemes of abstraction. The representation of individuals through data, however, is not limited to the productive economy or the algorithms of resource allocation.

Personal datafication has become an increasingly dominant form for representing the individual across many areas of life including health, sex, genetics, social interaction, travel and consumption. The push towards datafication of personal information is a multidirectional phenomenon with individuals opting to take up a number of data production practices – self-tracking - either at their own will or at the behest of employers and governmental or institutional actors. In other cases, computing systems are being used to analyse data about individuals and their behaviours as a means of targeting or customising products or services. Increasingly, however, it can be suggested that these abstract entities are becoming the primary site for engagement between individuals and others: commercial entities, institutions and the state, and in many cases engagement with the self. No longer correlates for real entities the abstract becomes a subject in itself a distinct and important part of the heterotic super individual assemblage. The increased prevalence of these datafied relationships between individuals and institutions is clearly visible across many areas of society (despite various public and regulatory challenges to specific actions) – credit ratings, user reviews, purchases (Clover 2016), Facebook comments (Ruddick 2016) and prison sentencing algorithms (Angwin et al. 2016) are used to determine trustworthiness or risk; DNA records are used to determine predisposition towards certain illnesses or to determine life assurance premiums (Joly, Feze, and Simard 2013); self-tracking and employer tracking practices seek to extract value from abstracted physical (Brown 2016) and affective activities (Moore and Robinson 2016).

The representation of the individual as a series of data points is probably most developed in the area of genetics and bioinformatics, where individuals are represented through their decoded DNA sequence consisting of approximately three billion data points. In practice, the most common form of representation of an individual's genetic makeup uses the single-nucleotide polymorphism approach, which analyses the individual's difference from a reference human DNA sequence based on the DNA of a number of individuals in Buffalo, New York. The use of an individual's DNA sequence is used in a variety of areas from health screening, to insurance assessment (Armstrong et al. 2003), employment selection (French 2002) and criminal trials (Gans and Urbas 2002). This representation of the individual as a series of digital codes that programme the individual as a physical entity it can be suggested positions the physical self within the informatics constructions that were highlighted in *Section 3.3*. In such a way the individual's physical manifestation can be thought of in information theoretic terms in which the DNA exists as input code and the abstraction of the physical form – measured within the general schema of medical diagnostics and bioinformatics exists as output. This input output relationship gives rise to the possibility of gene editing technologies currently in various stages of development such as CRISPR which allows for individual parts of the DNA code to be replaced, removed or edited. It is possible then to suggest within this scheme that the physical manifestation of the body becomes subordinated to its genetic code and the metadata attached to this.

The comparison of the decoded individual to the reference standard has practical considerations in the field of genomics, reducing the total amount of information required with which to describe an individual and creating a basis by which the common or seemingly inactive genes can be ignored in analysis. The concept of representing a human's traits physical, behavioural and neuropsychological with reference to either a standard base or through a supposedly objective clinical system has, however, been an issue of deep political implication throughout human history, but in particular since the growth and development of eugenics in the end of nineteenth century. Proctor, in particular, notes the links between the history of eugenics across Europe and the United States of America and the holocaust (Proctor 1988). Bauman, who also makes this link, suggests that DNA sequencing, representing humans as a dehumanised ‘race material’ not only builds on the history of eugenics in promoting a “racial hygiene”, or the notion of an optimised individual, but also contributes to an overall dehumanisation of personhood (Bauman 1991, 44-47). It is, as Ian Hacking points out, no surprise that the statistical models and concept of norms are so closely associated, he notes, ‘Karl Pearson, a founding father of biometrics, eugenics and Anglo-American statistical theory, called the Gaussian distribution the normal curve’ (in Foucault 1991, 83). Each of these datafications of the human and their behaviour, it can be suggested, exist as examples of representing people as a series of dehumanised variables as opposed to embodied humanity.

Another dominant area in the field of personal data, and one that compliments the use of DNA, is that of lifestyle, health and fitness tracking. In this case either users or healthcare professionals track activities and bodily functions/effects as a way of monitoring performance of either treatments or activities, or as a way of accessing services or goods (Lupton 2013). The use of these trackers varies from clinical uses, social uses and personal tracking, however in most cases the primary aim is to represent an individual’s activities within a numerical matrix such that users, that is data consumers, not producers, can apply some form of algorithmic decision making to the data, be it for advertising purposes, insurance price or risk categorisation, employment benefit, or even prison sentencing terms (Brown 2016). Broadly speaking the process involved in the creation of these abstract entities can be seen as similar to the AR theory definition of computing described in *Section 2.2.2*. The individual is represented as a series of abstract data points using measurement practices that produce an abstracted version of the individual, an infra-individual as described by Rouvroy above. These data points then become the basis for decision-making processes that can be acted upon within the abstract domain, the results of which produce affects in both abstracted and real domains. The short scene described by Critical Art Ensemble at the opening of this section describes the way in which the abstracted version of the individual becomes in many cases the primary site for the decision-making process within a logic of computation. This form of algorithmic decision making has, however, come under scrutiny for entrenching pre-existing forms of inequality or expressing biases that have their basis outside of the scope of the data used for analysis (Newell and Marabelli 2015). In other words, when historical data guides decision-making processes the possibility for those decisions becomes rooted in the historical data and decisions reproduce historical biases. At the same time, decisions come to be made only on the portion of information available within the abstract domain, and so the subject is conceived of in these terms.

In addition to the way in which data consumers and institutions apply the results of algorithmic decision-making process, the impact of self-representation through data has implications for the understanding of self and the value placed on activities and social relations. In particular, self-tracking practices are linked with ideas of self-optimisation both with respect to an arbitrary set of norms and within a social paradigm of economic productivity (En and Pöll 2016). The trend towards optimisation within the scope of the recorded data creates a bias towards experiences that can be tracked and recorded in numerically renderable visual results. Lupton, a leading sociologist of self-tracking practices notes that, 'The emphasis on the visual often works to erase other ways of knowing about the body and render fleshly human bodies into informatic body objects. This tendency has been intensified by the introduction of new digitised ways of monitoring and representing bodies, illness and disease' (Lupton 2015). Lupton notes that amongst users who have become habituated to self-tracking practices activities that are not recorded also become mentally discounted such that the datafied representation begins to take precedence over the lived experience (Austen 2015). Lupton goes on to describe how practices of self-quantification act to construct a view of the body as a machine with inputs and outputs that can be optimised as mathematical functions. Beyond this, however, bodily sensations she notes become subordinate to their mediated form as abstractions contributing to the overall data body, extending the physical into the abstract domain (Lupton 2013, 27). This effect is also discussed by En and Pöll who note that in the use of sexual activity trackers users felt the pressure to perform in order to 'impress the app' (2016, 38). In this case the complex social, cultural and psychological factors and activities involved in sexual intercourse become flattened and denuded of complexity through representation as data points through which the action becomes reconstructed.

Beyond highlighting the way in which the abstract entity becomes a primary site for engaging with the physical self, En and Pöll also recognise that the self-tracking user is required to grapple with the ontological question of what constitutes sex and apply this judgement in the creation of the datafied, and optimised, self. This observation highlights the difficulties that emerge in the application of measurement technologies and abstraction to the complexity of human existence and social relations. As was seen in *Section 2.2.1* the act of measurement requires that in order to create an abstraction that can function within a shared system of measurement it is required that the phenomena which is measured displays properties of discreteness, definiteness such that the abstract entity discriminates between real phenomena. As such the measuring relationship is, as we saw in Barad's work, the drawing of a line around the phenomenon to identify that which it is and as such that which it is not. In the case described by En and Pöll it becomes clear that the measurements involved in the quantification of the self also require this same grappling with the ontological question of what constitutes a phenomenon, such as sex. The result of this ontological question is not just attempting to find a common ground with which to describe the messy, blurry and contingent nature of human actions but as we have seen with Lupton and others what also happens is that the phenomenon comes to be reconceived of as that which fits within the ontological categories we use for its description. It is possible to suggest that the act of self-quantification contributes to redefining experience in universal terms rather than subjective ones. This feature of computational logic, that is central to the functioning of computational systems, will be discussed in more detail in *Section 4.3*.

The creation of the datafied individual, or of representational data about individuals, gives rise to a number of new phenomena that intersect with the representational economy discussed in the previous section. Secondary data markets, companies that sell data or data access to others, further act to increase the separation of the individual and the represented self that exist upon the communications network. The data entity dislocated becomes an increasingly dominant part of the being/representational hybrid – capable of acting and being acted upon without control from the physical entity. The vast majority of personal data created through the use of tracking apps, websites and social media platforms remains the property of the platform owner and is increasingly traded as a commodity (Schwartz 2004), the datafied individual becomes, as with digital currencies, no longer representative - that is of the individual, but representational – of an implied super-individual – an increasing portion of a heterotic assemblage.

What the example above suggests is that increasingly, as with the representational structures of economy, the individual is increasingly thought of in abstract terms. What is also suggested, however, is that not only is the individual constructed as a series of data points in the domain of economic action but that increasingly the individual's sense of self is also being reconstructed in these terms. Whilst this can be seen in the examples above it is perhaps most easily seen through the example of cyber-terrorism or cybercrime. As with conventional definitions of terrorism, there is some debate about what constitutes a terrorist act, or what separates it from either a legitimate act of war or an act of criminality. If, for example, we accept the United States of America's governmental definition, however, we arrive at, 'Cyberterrorism is the intentional use of threatening and disruptive actions against computers, networks, and the Internet' (Matusitz 2005). Even allowing for other definitions, what this constitutes is a distinctly different understanding of terrorism from that traditionally accepted:

> *Terrorism is defined as political violence in an asymmetrical conflict that is designed to induce terror and psychic fear (sometimes indiscriminate) through the violent victimization and destruction of noncombatant targets (sometimes iconic symbols).* (Bockstette 2008, 8)

The critical difference between the two conceptions is the introduction into the definition of non-human bodies, in other words that an act of terrorism can be perpetrated against a representation – a collection of data that is incapable of the sensation of terror. Yet the fear of cyber terrorism is present within the real bodies of individuals (Debrix 2001). In other words, individuals express real sensations of terror when there is a perceived threat towards the abstract representations that are related to their real person. In this way we can see how the infra individual becomes an increasingly constituent part of the super-individual and the abstract increasingly conflated with the real.

As with all these examples, relating to the represented individual or the wider representational economy or society, each displays a different level to which the representational appears to act as an entity in its own right delinked from physical material. In some examples the heterotic combination of abstract and physical act as the unit of engagement whereas in others such as money the abstract almost completely dominates. At the same time there appear many areas in which the abstract representation tends to be less advanced. It is possible however to suggest, even with this limited, survey that there is an increasing trend towards a representational mode of being in contemporary society. Within the logic of computation, it appears the ontological objects of existence and their representations become ever closer such that their existence becomes a function of their representation within the global scheme of computation. In the next section we will examine the driver of this convergence towards a point at which being becomes more fully entangled in representation.

4.3 A Reciprocal Engine of Actualisation

> *Just as geometric space constitutes itself by enacting the "death" of existential space, by overriding the physical object and the observer's intuition of diversity, so a certain immediate and global intuition of man, the unimpeachable testimony of consciousness with respect to man's states and his representations, experience lived as a signifying totality by a subject or a group, must give way to the results of processes that depend on breaking with that intuition, that testimony, that experience. – Louis Marin*

In the first part of this chapter we have identified how the abstract representations of computation affect a convergence between representation and being. Thus, it is necessary to try and understand what drives this convergence and see how a logic of computation may differ from changes brought about by other ways of knowing. In this section we will talk about representation as a way of knowing in the world and we will see how the abstract representation of computation alters the world in which it operates by producing increasingly abstract ways of knowing the world. The first part of this section will see how the central functional element of a representational system is the sharing of an ontology with which to relate the world to the abstract entities of the representational domain. As will be seen in *Section 4.3.1*, the logic of computation that was identified in the previous section is related to the development and standardisation of measurement systems as a way of abstracting the physical world. In particular what can be suggested is that the representations that are central to our definition of computation are based upon a strict encoding and decoding relationship between the real and abstract domains. In this way they depart from the types of representational systems, such as in language, that allow for interpretative flexibility and contextual understanding.

Having developed an understanding of the way in which the representational systems of computation require the coordination of a shared ontology in order to function, *Section 4.3.2* will explore the theory of Henri Bergson in order to examine the way that perception and affect interact with these representational structures to shift our understanding of the world. In particular the section will examine the way in which the representational structures of computation can transmit and hold certain types of knowledge whilst other types of knowledge recede within this context. The section will examine the interrelated concepts of memory and perception to propose a way in which the increasingly representational construction society identified within *Section 4.2* forms part of a reciprocal process that drives an ever-increasingly representational understanding of the world.

Having seen how the interrelation of our memory and perception shifts our understanding of the world such that the increasingly representational construction of the world gives rise to an increasingly representation understanding of the world the final section of the chapter examines the information theory of these computational constructions. In particular, *Section 4.3.3* demonstrates how in order to maintain the functioning of a representational system such as global logic of computation, or a global understanding of the world in representational terms, there is a requirement to coordinate the understanding of concepts amongst individuals and machines such that phenomena become described within the standardised framework of a global representational ontology. The section examines how an increasingly representational understanding of society requires this convergence of individual understanding of phenomena in order to maintain its ability to function based on the theory of Claude Shannon.

4.3.1 Representational Knowing in the Human and the Machine

Proposing a convergence of representation and being towards a point where being is actualised within the context of an abstract representational framework requires that we examine the implications of representation itself as a way of knowing and as a way of sharing knowledge. Representation, the ordering of the world through a system of signifiers and signifieds, has an important place in many philosophical standpoints, from Cartesian representational realism to the internal representational orderings of phenomenology. Here, however, having defined computation as a system based on the thinking of the world through abstract representations it is necessary to examine what it means to talk about representation in this way. What is at stake when we talk about representation is not only the interrelation between the representation and its referent – the abstracting relationships discussed previously - but also the way in which a representational system exists in order for it to function as a form of communication. In other words, in order for it to convey some meaning about the world. As we saw in *Section 2.2* the central concern of the abstract representations that form the basis of computation is the ability to communicate some aspect of a phenomenon such that it can be understood independent of the phenomenon itself. For representation to function in this way, what is required of the abstract representational process is the ability to encode and decode phenomena in such a way as that an understanding of the phenomenon can be reproduced from the abstraction. In the abstract representations of computation there must be a strictly understood relationship between the real and abstract domains in order that transformations and communications can happen in the abstract rather than real domain and, as we saw in the discussion of AR theory, that actions in the abstract domain can be assumed to correlate to actions in the real domain.

Generally, the representing part of the relationship between an abstract representation and that which it represents has been thought of as a semiotic relation. In other words, the abstract representation acts as a “sign” for that which is represented. For example, in Saussurain semiotics the idea of representation is held within the concept of the dyadic sign, that is that a signifier may relate to its signified only to the extent by which it cannot be said to relate to another signified. If we recall the theories of measurement and abstraction discussed in *Section 2.2.* the dyadic sign can be related to the definiteness of the measuring relation, which is to say if, for example, we measure or encode a physical entity as being of length one metre, what we are saying is that its length cannot also be expressed as two metres. In this way a representation derives is meaning only in as much as it can discriminate between entities consistent with the logic of the abstract space in which it operates. This relationship is the key for the signifier’s ability to represent that to which it refers and as such to convey information. In the later part of this chapter (*Section 4.3.3*), we will see that the ability to discriminate between abstractions is a function of the size of the representational system. The informational efficiency is determined by the smallest number of signs that can discriminate between the totality of referents.

In the semiotics of Saussure there is no *a priori* relation between the signified and the signifier that gives rise to its form and its structure, rather its existence is defined pragmatically through its functioning as a representation. As such Saussure’s semiotics is similar to the conventionalist aspects of measurement systems discussed earlier in

Section 2.2.1[37]. Marin highlights this importance of system in Saussure's sign construction, 'Thus the notion of system is central in Saussure, as any linguistic object finds its reality only through the play of relational differences within the system as a whole' (2001, 6). In other words, a sign finds its meaning in and abstract system in as much as it is capable of differentiating one element of a system of referents from those elements to which it does not refer. Importantly, Marin recognises, a sign system, in the case of Saussure - language, is based on a formalisation of differences to employ its effectiveness. He notes, 'To say that language is a totalization of differences, producing meaning through oppositions, is to affirm its dialectical nature and by the same token the dialectical nature of scientific knowledge of language' (ibid, 7).

Of course, Saussure's concept of sign system was inherently concerned with a linguistic system, and much poststructuralist theory which countered semiotics discourse such as Levinas, amongst many others, have highlighted the contingency which this system in practice must be seen to contain,

> *Experience, like language, no longer seems to be made of isolated elements lodged somehow in a Euclidean space where they could expose themselves, each for itself, directly visible, signifying from themselves. They signify from the "world" and from the position of the one who is looking* (2006, 12).

Language and experience the poststructuralist position suggests are not capable of being objectively fixed in mathematical space but rather their understanding is based on the context of the receiver. Derrida too highlights this point with his assertion that, 'there is nothing outside context' (1990, 136), a phrase that originally mistranslated as, 'there

[37] Recalling the survey of measurement from earlier, the conventionalist aspect of measurement systems does not imply a purely conventionalist approach to measurement. Rather, each system of measurement includes some aspects of conventionalism which order the practices of measurement in a way that is communicable to others. What we refer to as the conventionalist aspect of these system is then just the language of measurement as opposed to its theory.

is nothing outside of the text', (1997, 158) exists an example of the contingency with which signs are employed to produce their meaning. As we have seen earlier in our discussions of computing technology the mathematical systems of representation with which we are concerned display these same properties that Saussure highlights for a linguistic system – the requirement to discriminate the physical phenomena that they denote. In fact, what we will see is that whilst this ability to discriminate is essential to the functioning of any representational system – the difference between a computational system of representation such as we have discussed and one such as human language or semiotics, is the possibility of their functioning when the relationship between referent and representation is strictly encoded or open to the possibility of interpretive flexibility.

The key to the functioning of a representational system is that for a representation to convey meaning, or to convey its referent, there is a requirement for some *a priori* structuring system or convention through which this representation denotes a referent at the discrimination of others. In the case of the representational structures computation, as we have seen, the relationship between the real entity and the abstract entity must be strictly encoded in order that the abstraction can be understood in a predictable way by a computing machine. in either a semiotic/structuralist or poststructuralist understanding, or in any of the measurement theories we discussed in *Section 2.2.1*, this convention has no causal link to the referent and therefore is a product of the system and the making of convention. That is to say that a representational system is an ontology – a categorisation and classification of all that is – that is generated productively for the transferal of meaning. As we have also seen earlier, a representation is a subtraction from the total meaning of the entity where the specifics of this subtraction are mediated by the framework in which the representation is produced. For example, within the representational structures of computation this subtraction as a minimum is of those elements that cannot be represented in the form of the abstract structures (for example in the mathematical structures of computers) on which computation is based. Recalling Saussure's dyad, the subtraction also includes those features that cannot be determined or distinguished from other entities within the real space or those features that are not required to produce a discrimination between the entities in the abstract space. It is possible to suggest then that a representational system is one that is inherently reactive, in other words it is produced in response to the world. The production of a relationship between representation and referent follows the existence of the referent and the attempt to communicate it.

As with the production of representations – the abstraction of the real into the abstract domain - the act of encountering a representation - the instantiation of the real from the abstract - exists as a reactive process. The apprehension of some representation follows sensation, as one that makes sense of sense data through reference to some bank of pre-existing situated knowledge as to the relationship between the sense data and the referent. In the case of computation this encountering too is based on a strictly encoded ontology in which the sense data, be it encountered by a camera, heat sensor, network port must be translated to reproduce the meaning of a real phenomenon based only on that information contained within the abstract domain. As such the reproduction of the real from the abstract domain is such that only that which is abstracted can be reproduced. In other words, that which is lost in the production of the abstraction cannot be reproduced in the process of instantiation. This strict encoding/decoding relationship and the ability to consistently reproduce the abstract from the real and the real from the abstract is however central to that which makes computation function, namely the ability to transfer and manipulate a phenomenon in its absence. This communication however requires that the strict encoding and decoding relationships are shared.

The ability for representations to be shared amongst groups of people is therefore based on the sharing/coordinating of the encoding ontology that contains knowledge commonalities between individuals. For example as we saw in *Section 4.2.1* for a majority of European individuals today time represented through the system of the clock contains meaning that can convey the idea of a present moment within passing, but also the concept of duration, whereas historically for Aboriginal people in Australia the representation of time is inherently linked to geography and the path of the sun (Adams 2009). A common representation then has the possibility of conveying multiple meanings depending on the situatedness of the receiver of the representation (as proposed above by poststructuralism or postmodernists).

The interpretative flexibility of representations based on the situatedness of the receiver is of course a cause for misunderstanding, or for understanding differently – the encoded meaning not being retrieved fully in its decoding. The attempt to remove this interpretative flexibility is at the core of where global computation however diverges from the imperfect communication of, for example, language. Computation, as we have seen, requires a representational cardinality between referent and representation that is a defined and differentiable encoding decoding relationship. A global system of computation therefore requires a total ontology such that each representation is universally differentiable, understandable and translatable at each and every node of the heterotic human machine network. In other words, the project of global computation, of mapping the world in a way that can be represented in the abstract representational structure of computation can be suggested as the attempt to define the world in terms that are unambiguous and in which ambiguous communication, or misunderstanding is removed.

A universal ontology of representation, translatable to all nodes within the network, requires the coordination of local knowledges – where local here denotes knowledges to a resolution of the individual human or machine as opposed to larger bounded groups. That is to say that within the logic of computation local knoweldges and local understandings must align with the universal ontology in order to decode and encode messages. This universal communications then requires a movement in two parts, firstly that local knowledges converge to universal knowledge (i.e. that common methods are used to encode/decode phenomena) and secondly that new knowledge is created in the form of the universal system of representation (i.e. that phenomena are described and thought of in terms of these encodings).

Of these two movements, the latter is the most easily achieved as knowledge is produced within the constraints of the available methods for its production and dissemination/ At the same time we have seen in the last section, *Section 4.2,* how the tools we use to describe knowledge reshape our understanding of the underlying phenomena themselves. Within an increasingly computationally constituted society this can be conceptualised as saying that new knowledge production is governed by its performativity criterion – the ratio between its input and its output – its ability to be conceived of, manipulated and shared on the computer network. In other words, within a knowledge system dominated by the technological apparatus of modern computational and networking software and hardware, knowledge that is easily transmittable across this network will predominate over those forms that cannot be transformed into computer readable forms (Lyotard 1984). In a society that is increasingly constituted by a logic of computation then it is possible to suggest that increasingly new knowledge will be produced in the form of the universal ontology of its encoding. This movement towards the constitution of performative computational knowledge is also the element of this tendency that is most greatly influenced by market forces of neo-liberal capitalism and new forms of political economy[38].

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[38] There is much literature on the link between technology and what is described alternatively as late-capitalism, liquid-capitalism, communicative-capitalism, post-Fordism, techno-capitalism or myriad other terms. (See: Lyotard (1984), Bauman (2000), Kellner (Kellner 2002) , Hardt and Negri (2000), Suarez-Villa (2012) (2009), Thrift (2005), Castells (1996), etc.) In general, despite different approaches and perspectives, this work highlights a distinct link between current

The first movement – the convergence of local/subjective knowledges so that existing understandings are thought of in universal terms – that initially seems more difficult, is also easily achieved in the structure of a computationally constituted society. This movement, the convergence of local knowledges is produced in a reciprocal arrangement with the first such that both movements are interlinked and self-repeating. The first movement is precipitated through the second such that as new universally represented knowledge is created in place of pre-existing local knowledges the field of local knowledges decreases and new areas of knowledge become representational. This tendency is also visible in the examples described in *Section 4.2 g*. The point here is that the field of knowledge is not fixed but rather it constantly shifts depending on the technologies and milieu in which it is produced – a point discussed earlier in the discussion of Kuhn.

In other words, it is possible to suggest that knowledge and understanding rather than being fixed are constantly reproduced based on the available tools with which they are produced. In the following two sections we will look at two features that give rise to the convergence of local knowledge into a universal understanding of phenomena. The first explores the way in which the representational knowledges of computation become embedded in our understanding of concepts, the second looks at the information theory that governs the transmission of representations in computing machines.

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technological developments and capitalist economics. Much of this work highlights the production and commodification of data in the business models of powerful private transnational companies and an associated privatization of various state functions with respect to this data. It is not necessary, nor possible to discuss this in more detail here, and this subject has in isolation filled the pages of many other projects. However, it is necessary to point out that despite the implication of an explicit relationship between communications technology and capitalism these works cannot be generalized as being purely technologically deterministic. Rather, these works highlight a reciprocal relationship that is both self generating and situated in the political economies in which it has developed.

4.3.2 Perception, Affect and Memory

In a society dominated by networked computation individual understandings of phenomena must converge to a universal ontology. In order for this to happen the locus of understanding must move away from the individual's subjective classifications of phenomena towards a universal ontology. The apprehension of a representation must not be decoded subjectively but in terms defined within the universal ontology. In other words, the understanding of phenomena themselves must be contained within the apprehension of it – phenomena must become super-phenomena containing their meaning and the meta-information for understanding their meaning. Phenomena must become understood in terms of the ways in which they are represented. As was seen in *Section 4.2* this process for time, or for the datafied body is already well under way. In a heterotic assemblage of human-machine understanding, as we have seen, representations must be strictly encoded, their value equally legible to machines and to humans. Thus we can consider this as a new way of understanding that is neither fully contained in mind/concept (idealism) nor in the material (realism). This new understanding requires a refitting of existing philosophical divisions marked at one end by materialist realism and at the other by the idealism of the mind. Instead the universal ontology marks the existence of an expanded heterotic consciousness contained between mind and matter.

Initially the idea of a universal ontology – the physical world completely mapped into the abstract - might appear to mirror most closely the idealist understanding of the world - the idea that the world exists as a system of concepts and ideas rather than material reality. As Jeans describes, this idealist view is operative in the field of physical sciences in scientific and mathematical modelling,

> *To-day there is a wide measure of agreement, which on the physical side of science approaches almost to unanimity, that the stream of knowledge is heading*

> *towards a non-mechanical reality; the universe begins to look more like a great thought than like a great machine. Mind no longer appears as an accidental intruder into the realm of matter; we are beginning to suspect that we ought rather to hail it as the creator and governor of the realm of matter—not of course our individual minds, but the mind in which the atoms out of which our individual minds have grown exist as thoughts. (2009, 137).*

However, it is possible to suggest that this new form of knowing would sit equally between realist and idealist interpretations. A reality that is actual only in its representation finds its existence in the idealism of concepts but as Jeans describes not within the concepts of the individual mind, but an external set of concepts. The universal representational structure therefore becomes the structure through which the real is actualised. Thus, we can suggest that the real becomes only that which can be made possible through its representation – that which cannot be represented thus becomes invisible, non-represented, non-thought, non-matter. In the computationally structured society visibility, and therefore existence, is contained in the ability to be represented and existence becomes the form that the representation takes.

To understand the implication of this new way of knowing – the convergence of what *is* and what *is represented* we must examine the interaction of the material world and the world of concepts. One strategy for examining the surface that lies at the intersection of these two spheres is to journey topologically upon the surface as if unaware of the histories of thought that bend and skew the surface itself. This approach is that employed by Bergson in *Matter and Memory*. Here it is useful to follow Bergson's path so that we can, as he does, proceed with the analysis of this new way of knowing without the need to resolve disputes between philosophers that lie on either end of the idealist and materialist divide (1991, 10). Instead, following Bergson's approach, we can examine directly the functioning of a universal representational structure itself. In doing so, we can see how the interaction of the real and its representation gives rise to a cycle of reciprocation through which it is reproduced and thus brings itself further into existence. Following Bergson's approach is not only methodologically useful but is necessary here as it can be proposed that the concept of memory he sets out closely describes a mechanism by which our understanding is altered through our worldly interactions. Bergson sets out his position that both idealist and realist accounts fail to account accurately for reality by trying to either explain material through the lens of perception or inversely explaining perception through the lens of materiality. In each case, Bergson notes that the there is required a *deus ex machina* that is required to explain how consciousness appears out of material or how, for idealists, sciences have the ability to predict future events (ibid, 26-28). Trying to understand a universal ontology requires a similar position in order to prevent the discussion collapsing into an attempt to solve old philosophical debates. In other words, thinking about the convergence of representation and being could otherwise require thinking of representation through being or *vice versa*. Instead, here an account of changing ways of understanding must allow for the way in which our perception of the material world is built into, and constitutes, our understanding of the concepts and relations that form our understanding of the world in which we exist. By allowing this openness to both a materialist and idealist structure we will see how the representational structures of computation can act to reform our existing understandings of the world into increasingly representational forms.

For Bergson our perception is explained by the interaction of a single "image"[39] (that is state of matter) – the individual - with other images – the material world. Perception then

[39] Bergson uses the term image to mean a state of existence of the world. In *Matter and Memory* he describes, 'Matter, in our view, is an aggregate of 'images.' And by 'image' we mean a certain existence which is more than that which the idealist calls a representation, but less than that which the realist calls a thing, -- an existence placed half-way between the 'thing' and the 'representation.' (1991, vii)

is a representation created by this interaction, where importantly the representation exists as some subtraction of the actuality of the image's whole[40]. In other words, perception is the world filtered by the subjective position of the individual. This subtraction we have seen before, in our discussion of representation within computation and within language, is defined by the subjectivity of the individual. A representation through which perception is created is therefore a subtraction from the whole based on 'necessary poverty' (Bergson 1991, 38) of the concerns specific to the individual image through which it is created, in this case the individual. In other words, the world we encounter is a representation of the material world mediated by our specific being, our concerns and perceptual limitations – our subjectivity.

The subtraction that reduces the world to an individual perception in Bergson's theory is informed by memory. This is to say that memory is the body of retained experience that forms the person's subjective standpoint. Memory Bergson proposes exists in different forms that constitute the self in the present and thus inform the way the self relates to the other images of the material world. Bergson outlines these forms in various divisions and using various schema such that a definitive taxonomy is not possible. Nevertheless, it is possible to suggest two main forms of memory in Bergson's model. One form is *contraction memory* that constitutes, 'a plurality of independent moments to constitute our enduring lived present' (Perri 2014, 838), that is to say the present self. *Perception memory* on the other hand 'informs the sense of and provides the content for every conscious perception to such an extent that one can ultimately say that 'there is no perception that is not impregnated with memories' (ibid). Perception memory then is an

[40] Recall here the description of representation from Chapter 3 – in which a representation exists as some subtraction of the entity to be represented – determined by standpoint or frame along with technical possibility for representation.

almost automatic structuring of the way we perceive new sensory information. It follows immediately our sensation and acts to mediate the way in which new knowledge is formed from our interaction with the world. These two forms of memory exist in a circular arrangement where the memories that form our contraction and perception memory are shaped by the representations that constitute our perception. In other words, our memories shape our perception and our memories are composed of the accumulated total of our perceptions. The possibilities of perception then are intrinsically linked to that which forms us as subjects. This interrelation between our perception and memory acts as the engine of a reciprocal arrangement, where new knowledge is shaped within the framework of that to which we are exposed. Bergson notes, ‘In short, memory in these two forms, covering as it does with a cloak of recollections a core of immediate perception, and also contracting a number of external moments into a single internal moment, constitutes the principal share of individual consciousness in perception, the subjective side of the knowledge of things’ (1991, 34). This interrelation it can be suggested is the cycle through which subjectivity is produced.

Perception, the creation of subjective knowledge, then is the intersection of the plane of material images (the material world) with that of the subjective individual (the collected memory of the individual – the world of idealism). Bergson uses a diagram (*Figure 4.1*) depicting the tip of a cone intersecting a moving plane (P) to describe the subjective experience (S) of the individual composed of their memories (the cone SAB). In the diagram P represents the material worlds whereas the cone, the individual shaped by their subjectivity, filters that part of the interaction into themself. Through this understanding of perception it is possible to see how the representational structures of computation might become increasingly embedded in our understanding of the world. In the case of computation, however, the representational structures of computation act prior to perception. The plane of images that make up the material external to the individual world becomes filtered as abstract representations. Human perception then takes on this double subtraction from the images of reality by which we are surrounded. As we saw in *Section 2.2.1*, for the representational systems of computing the representation of any entity (an image in Bergsonian terms) is a subtraction from the entirety of that entity based on the poverty of representational limits of the computational structure and its encodings. More importantly, in order to communicate between individuals, it is a subtraction that is mediated by an even greater poverty, the need for an encoding/decoding relationship that is relatable between individuals. Representation within a universal ontology is thus a subtraction from the entity of all that is not understandable equally to all, both human and machine. Thus it can be suggested it is the elimination of the subjective in favour of the universal. The representation of reality in a universal ontology is then not only reduced by the poverty inherent in a single perspective but it is the further reduction of that image to a representation that includes only the commonalities between each individual perspective. It is a double subtraction that is made necessary by the need to have a shared way to represent the phenomena of the world.

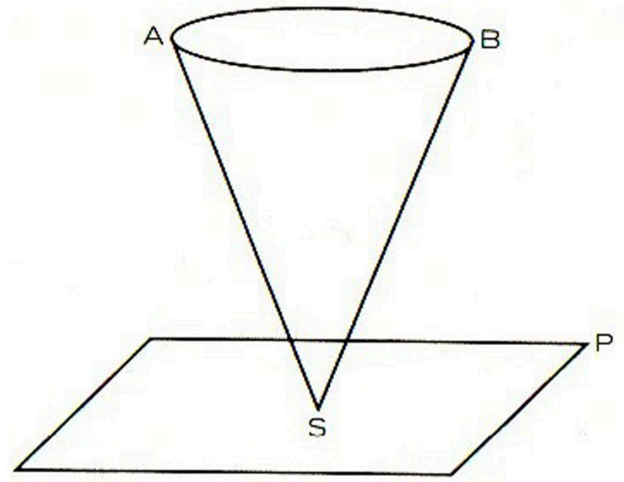

Figure 4.1 Bergson's diagram of the interrelation between the memory and perception. The individual (SAB) perceives the world subjectively through the interaction of S, their subjectivity, and the moving plane of existence (P). (Bergson 1991, 152)

The representational structures through which we interact with the world can be thought of as a filter that mediates the surface of individual perceptions. In the same circular arrangement as our subjectivity is produced by our interaction with the world the computational logic is produced by altered subjects whose collected memories are derived from the perception of an increasingly representational existence. A system of representation thus is not only a filter that mediates our perception within an unchanged world, but it becomes a constitutive element of the way in which we think of and produce the world itself. In this way, it is possible to suggest that representation interlocks with the cycle through which our subjectivity is produced. Bergson's circular conception of the relationship between subjectivity and perception provides a good basis for understanding the way in which knowledge changes and new ways of seeing the world can be reproduced. It is not enough, however, to propose that the abstract representational structures of computation exist as a filter that shapes our knowledge and alters the possibility for its creation. In what we have seen so far in this section computational representation as a way of altering our understanding of the world seems to offer no particular feature that separates it from any other form of changing knowledge. It is necessary therefore to examine what it is about computation logic that drives its reproduction. What we will see is that the power of this reciprocation is bound up in the limitations of computational representation itself.

As has been discussed in *Section 4.3.1* representational systems require the existence of an *a priori* structure with which a perceived or given state can be related to some idea or concept. For human cognition, cognitive and neuropsychology describe a representational relationship through which our perception is formed. The representation is some assumed abstract representation or isomorphism to the external world, and thus cognition happens through the manipulation of these representations (A. Morgan 2014). Cognition therefore follows perception and new sense data is framed through its relation to the structural representational models that are contained within the mind. This can be related to Bergson's concept of perception memory – in which the external world is decoded with reference to our subjectivity. The abstract representational structures of computation operate in a similar fashion with the external world being translated through abstract representation (many examples of which we have seen in *Section 4.2*). With cognitive representation in neuropsychology, or the memory/perception interaction described by Bergson, the summation of previous experience acts as the referent system by which new perceptions are encoded as representations. In the case of computing representation, however, the summation of previous experience (subjectivity) is replaced by the abstract representation model employed. In other words, rather than experience, computation relies on the encoding and decoding relationships by which the real is translated to and from the abstract domain. And so whilst computational representation is presented as similar to the cognitive structures of the brain (and indeed the advent of computing was critical in the development of the cognitivist approach to psychology that has dominated since the latter part of the last century (ibid, 214)), unlike cognitive processes of the brain for computation the representational relationship is defined before perception and with reference to the universal, rather than subjective, encoding. Therefore, computational choices for cognition are made *a priori* of sensation.

It is possible to suggest that for computational cognition there is a relocation of the understanding of action from that of the event to that of the model. Computational systems makes reference to the external world through a predetermined set of rules, whereas for the individual the cognition is preceded by affect (Zajonc 1985) (Zajonc 1980). In fact, this, as we will see below, is a key difference between the types of representational knowledge produced by computation and other types of knowledge. The role of affect in cognition, or as a precognitive function, is contended differently in various psychological models. (In part this contention, it may be suggested, is related to a conflation of the terms affect, emotion and feeling, and some clarity is required here.) Affect, as will be discussed here is used to term something that causes a change in intensity of one state to that of another. This reading of affect, which takes its bases as in the work of Spinoza (2002, 278), Bergson (1991) and Deleuze and Guattari (1987) sees affect as the interacting force between bodies (Bergson's images) in the material world. Here we can take bodies to mean both physical and conceptual objects that cause some change in state upon the receiving, affected, body. Massumi sums up this interpretation succinctly,

> *'AFFECT/AFFECTION. Neither word denotes a personal feeling (sentiment in Deleuze and Guattari). L'affect (Spinoza's affectus) is an ability to affect and be affected. It is a prepersonal intensity corresponding to the passage from one experiential state of the body to another and implying an augmentation or diminution in that body's capacity to act. L'affection (Spinoza's affectio) is each such state considered as an encounter between the affected body and a second,*

> *affecting, body (with body taken in its broadest possible sense to include "mental" or ideal bodies).'* (in Deleuze and Guattari 1987)

Emotion and feeling on the other hand, which are often described using the term affect in both psychological and common discussion, can be seen as antecedents of affect in most psychological models. Feeling, generally is the conceptualisation of affect within the representational model of the individual, and its expression is emotion. That is to say, an affect is conceptualised as an emotion once the perception has been processed cognitively with respect to the individual's subjective position and their experience (Clarà 2015, 39) (Shouse 2005). Returning to affect, it can be suggested that affect can be thought of as the precognitive interaction with which we relate to the external world and thus that on which our perception is founded. For computing systems the relation to the external world, however, cannot be precognitive. A sensor or input device does not remap its relation between voltage and bit through a subjective interrelation with that which can be sensed. In other words, the sense data that is recorded from the external world is conceptualised in a fixed manner through the measurement relation through which it is determined. For computers, it can be suggested that affect has no role in computation.

The absence of affect in the relationship between an abstract computing architecture and the external world changes the form of the knowledge that is contained within this structure. Knowledge within a representational structure is removed of its affective component.[41] The absence of affect in computational knowledge is a function of the

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[41] It is important to say here, and it will be discussed further in the following sections, that this does not imply that a computer system cannot be the cause of an affect in an individual, or that and individual cannot be affected by representational knowledge. Whilst this remains possible – and whilst universal representation remains non-total – there remains the possibility of

modelling process of computational systems. In order for a representational system to produce translatable knowledge it is necessary that the system is designed so as to react in a predictable and consistent way to perceived phenomena. As such, the subjectivity of different responses to a phenomenon cannot be accounted for within a representational system. Individual subjectivity in a representational system is non-transferable as it cannot be decoded by a different subject. In the informational theoretic model, which we will examine in the next section, subjectivity exists as noise or system aberration.

In non-computational bodies, however, affect is received subjectively in the affected body, differing from one body to the next. This difference gives rise to the heterogeneity of perception and of response and cognition that derive from this differing state of affection. Affect, which acts differently in heterogeneous bodies is therefore abstract and unstructured. In other words, whilst it may exist as transfer between two bodies it is non-communicative in as much as there is no direct and explicit transfer function to describe the relationship between the affecting and affected bodies. Shouse describes this condition,

> *The power of affect lies in the fact that it is unformed and unstructured (abstract). It is affect's "abstractivity" that makes it transmittable in ways that feelings and emotions are not, and it is because affect is transmittable that it is potentially such a powerful social force' (Shouse 2005).*

Affect it can therefore be suggested exists as a causal part in a production of non-representational knowledge where the affecting body, be it an object, concept or idea, creates the conditions for the production of knowledge in the affected body. However, the knowledge produced by the affected body is outside of the control of the affecting

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unstructured interaction, in these cases the affective relation is that caused within the individual as the affected body and the data exists as the affecting body.

body. This open-endedness is central to the function of affective knowledge, or the affective component of any form of knowledge. Affective knowledge requires for its completion the subjectivity of the recipient and the affecting object continues to produce new and different knowledge in each different subject. This role of affect is described in a broad spectrum of contemporary theories such as Barthes (1977), Levinas (2006), Sartre (1948) amongst other modern phenomenologist, structuralist and post-structuralists and, as we saw in *Section 2.3.1*, the partial perspectives of feminist epistemologies. Affect it is possible to suggest is therefore non-representational or pre-representational. It is unrepresentable knowing. This difference between affective unstructured knowledge and structured representational knowledge gives rise to a central question of this thesis. How do we understand the implication of an increasingly computational society if computation strips knowledge of its affective component?

Before discussing further the knowledge within representational systems of computation it is worthwhile to briefly continue with affective knowledge. Affective knowledge, as we have discussed it, relates closely with "embodied knowledge" proposed in phenomenology in particular by Merleau-Ponty (2004) and in many respects the subject may be interchangeable the difference in terms being explained primarily through a difference in focus. Affective knowledge, however, is also closely related to a component of the "narrative knowledge" described by Lyotard (1984), however, in this case the connection may not be as obvious so it is worthy of explanation. Knowledge, Lyotard explains, is the totality of that which makes one capable of making "good" utterances, descriptive, evaluative or prescriptive. Lyotard notes that computerised/scientific knowledge exists as a subset of knowledge that requires that he describes thus,

> *'Knowledge [savoir] in general cannot be reduced to science, nor even to learning [connaissance]. Learning is the set of statement which, to the exclusion of all*

> *other statements, denote or describe objects and may be declared true or false .65 Science is a subset of learning. It is also composed of denotative statements, but imposes two supplementary conditions on their acceptability: the objects to which they refer must be available for repeated access, in other words, they must be accessible in explicit conditions of observation; and it must be possible to decide whether or not a given statement pertains to the language judged relevant by the experts.'* (ibid, 18)

Narrative knowledge, Lyotard goes on to say, exists as a primary form in which the non-scientific elements of knowledge are transferred, the knowing how to be, how to live [*savoir-faire, savoir-vivre*]. These forms of knowledge he notes are essential elements of the total knowledge that embody and comprise the subject (ibid, 19). He notes, however, that their transfer is embodied in the relation between narrator and receiver and as such these forms of knowledge have a highly affective component and cannot be disembodied from their holders.

As mentioned above, representational systems require that knowledge exists in a way that is translatable and repeatable such that communication is possible. At the same time, it is possible to suggest that knowledge in this form represents only a part of total knowledge. Computational systems therefore deal with a subset of total knowledge. This subset of knowledge, however, is not simply the totality of knowledge minus some affective component; rather the knowledge that exists within the representational systems of computation exist sas a series of accumulative subtractions. The first such subtraction is the subset of knowledge that can be mapped within a representational structure. As we saw in *Chapter 2* and earlier in this chapter, this includes the removal of subjective knowledge from the field of total knowledge. The second subtraction is the subset of knowledge that is actualised through interaction with representational structures. In other words, it is new knowledge that is created through interaction with already existing computational knowledge. In other words, it is possible to suggest, and as we have seen in examples from *Section 4.2*, that thinking *through* representational structures in turn produces increasingly representational knowledge. Which is to say that when we conceptualise a phenomenon or entity in terms of an abstract representation of it, the possible knowledge that we can produce about it derives from the form in which we perceive it.

The second point here is of importance as it acts as the reciprocal engine through which representational knowledge becomes the dominant mode of knowing within contemporary society. To understand this, it is useful again to consider Bergson's theory of perception and memory, and to consider how the reciprocal arrangement between these two exists. Perception as we discussed it can be seen as the point of intersection between two objects, the external world and the individual. This intersection is contingent on the form of the external world and the form of the individual. The individual as we have seen is shaped by memory, which is the accumulation of the previous perceptions through which it has been created. Each percept can be seen as the actualisation of some part of a field of virtuals. In other words, out of the totality of possible percepts a single percept is actualised through the interaction of the external world with the individual – all other possibilities becoming unrealised possibles. The external world is funnelled from the virtual into the actual (existence) in this way, for each individual the actualisation takes place based on the form of their subjectivity and their exposure to the external reality from the position in which they exist.

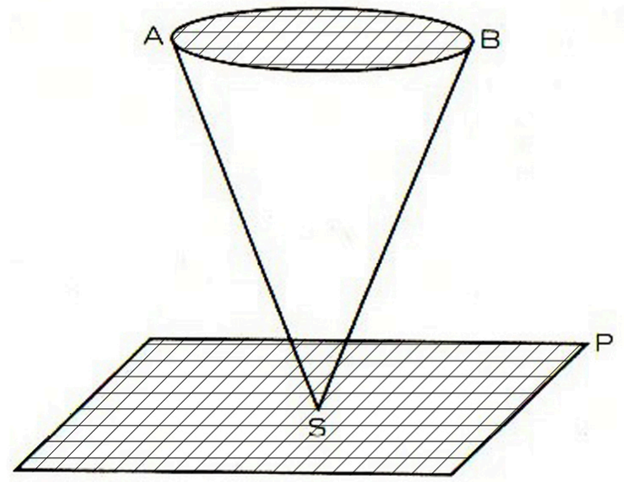


Figure 4.2 An altered version of Bergson's interrelation between memory and perception in which the filtered plane of existence (P) produces an altered subject.

If the world is perceived in increasingly representational terms then it is possible to suggest that so too the interaction of the world and the individual becomes increasingly representational. Representational structures become increasingly inserted into the circuits of this relationship. As a filter that sits between the external world and the individual, representation alters the structures of both. As the understanding of the world becomes universal the external world becomes encoded in these universal terms. The trace of the representational structures becomes part of the individual memory and therefore part of the perceptual relationship. New memory becomes actualised within this altered field of technological perception and the set of virtuals that become actual are shaped by this new representational perception. O'Sullivan describes this interrelation,

> *"It is the body–brain complex that actualises these 'things', although this actualisation is not uniform, for different subjectivities exist in different worlds, these worlds being determined by the various 'technologies' at each individual's*

> *disposal. Technology here is then the name for that which enables, but also controls and manipulates actualisation/emergence."* (2006,105)

If, as Bergson suggests, our memory and perception are interlinked in a reciprocal arrangement, then what does it mean for our understanding of the world when we relate to it through increasingly representational structures. As we discussed above representation requires an *a priori* set of rules for encoding the real within the abstract. These encoding rules form the basis of a representational structure that filter our understanding of the world and that thus become an increasing part of our understanding of it. At the same time, we have seen how the unstructured knowledge of affect, reliant on subjective interaction between bodies, is incompatible with the requirements of communication and transfer that are central to the function of representational systems. In the reciprocal arrangement in which the world is brought into existence by subjects and where representation overlays our interaction with the material world then it is possible to suggest that affective knowledge becomes diminished and that new knowledge is created in the form of representational knowledge. The trace of representational structures becomes watermarked in increasing intensity on our perception like the ink blotch on a photocopier page that has been copied repeatedly. At each new cycle of knowing and being the world becomes thought of as representational and our actions in the world become conceived of in respect of these representations. At the same time, those elements of knowledge that cannot fit within the representational structure become incrementally less visible - the subjective and affective, the local and the primitive, the bodily and the embodied each non-computable and non-representable become fainter and fainter in the reciprocal process of actualisation. Thus we can think of computation as altering the filed of virtuals – those things that can be made real. As we collectively begin to think through universal terms then so too the field of virtuals becomes that which is described within these terms.

4.3.3 The Information Theory of Contemporary Society

What we have examined above is how thinking *through* representation structures acts to create an increasingly representational construction of society. At the same time it can be seen that the structures of representation are incompatible with certain types of knowing. How does a change to representational knowing differ from any other technology that brings about changes in the way in which the world is viewed and which in turn become embedded in that view? It is not necessarily clear that the reciprocal production of representational knowledge contains within it something that could not lead to a representational way of knowing that is as heterogeneous as the myriad ways of knowing that exist now. Could it not be possible that a representational way of knowing could produce a different but equally multiple system of understanding the world – or does a representational system ultimately lead towards a convergence of the understanding of the world in common terms, through common concepts and through universal rules? Having examined how the representational structures of computing systems give rise to a mediation of our reality it is necessary to examine how a system of representation functions in relation to heterogeneity. By examining the information theory that describes the functioning of a representational system we will see how not only does representational alter our perception of the world but through a process of optimisation, our understandings must converge towards a universal and common understanding of phenomena.

As we saw in *Section 4.3.1* the most important component of a representational system, that allows it to function as communication, is the sharing of an ontology. In other words, for a representational system to convey meaning, the encoding and decoding relationship must be common amongst the sender and receiver. As Shannon says in the first page the seminal paper of information theory, 'The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point' (1948, 379). In information theory, as in the representational systems we discussed in *Section 2.2.1*, the relationship between the real and abstract domain is the encoding. As we have also seen, the relationship between the real and the abstract domain need not have a causal relationship, but for the representation to convey meaning it must be understandable to the receiver – they must be able to decode it. The receiver of the message must share the encoding relationship of that of the sender.

In a society that is increasingly constructed through representations, communication becomes the communication of representations, as opposed to through the unstructured communication of affect (discussed above). As such the increasingly representational way of understanding the world and the coordination of these understandings between individuals creates a need for a universal and an overarching set of transformational relationships between the real and abstract domains. In other words, as representational knowledge is used to describe ever more areas of our world, so too there is needed an ontology that includes a way to encode these new elements. Good communication of representations, that is where the message sent by the receiver is the same as that received by the sender, requires that the encoded output must represent the input in a definite way such that the representation can refer only to a single referent. For example, a chair must not be confused with dog or a length of 1 metre must not indicate the length of two objects that are not of equal length. This referential requirement, the encoding efficiency is described in Shannon's *Mathematical Theory of Communication*, where he describes the entropy of an information system. The entropy, that is the maximum possible meaning carried by the system, he describes, is at its maximum when for each possible input a single possible output is possible and where this is carried out with the least possible transfer of information. In other words, an information signal can encode the most information when its possible output states are equal in number to all possible input states, and each input state produces a unique output state (1948). As the world is increasingly structured through representational systems, so too the importance of Shannon's theory increases. In order to maximise the entropy of a representational system, or in other words in order to ensure the information systems performance in conveying information, equal cardinality of the representations and referents must be maintained.

It is worthwhile to dwell for a moment on this point, as it is significant for the purpose of understanding the way in which a representational system in practice tends to produce a coordinated understanding of phenomena between individuals. Shannon's information theory describes communication within an idealised representational system. In this case a channel of communication is thought of in its ability to transmit a message between two nodes where there is a non-infinite number of symbols and combinations and a non-infinite but lower number of messages that can be conveyed. In *Section 2.2.1* and in *Section 4.2* we saw how the world is increasingly conceptualised in terms of representations that have their roots in the attempt to create a set of abstractions to describe and communicate completely the physical world. It is possible to suggest that whilst representation forms an increasing part of reality, it does not yet form the totality of our reality. In this way it could be suggested that a representational system for describing the world exists as a finite set of symbols that attempt to describe a finite set of messages. However, if we think that that which is represented can be understood subjectively it is possible to suggest that, even in the current state of advancement of representation as a way of describing reality, there exists a system in which a finite number of symbol combinations attempts to describe an indeterminate and thus potentially infinite number of messages. In this case the potential number of messages would exceed the number of possible ways to describe it and as such a representation would have to describe multiple different elements. Therefore, in order for the representational systems to function as a means of communicating the phenomena that they are given to describe, the representational system must expand in order that it can properly account for the increasing number of elements that are represented.

Maintaining the cardinal relationship between representations and referents, that is that the number of elements in the set of represented things and in the set of representations requires two corollary movements. The first movement, which can be seen in the attempt to represent ever-new phenomena within the representational system, involves the creation of new representations, the mapping of emotions, time, value, space, etc. within a representational ontology. This first movement can be thought of as the expansion of the representational system in the attempt to accommodate ever-new phenomena. The implication of this movement is that in order to represent the heterogeneity of the world in all of its subjective perceptions the representational system would require an expansion to a potentially infinite size. The challenge proposed by this expansion gives rise to the second movement. The second movement happens from the opposing direction, in order to maintain a one-to-one relationship between the referent and representation, this movement in contrast to the first is a form of convergence. The convergence functions to maintain the cardinal equality in the domain of the referent rather than that of the representation. In other words, the convergence acts to limit the number of potential referents. If the expansion acts to find new representations for each referent, the convergence acts to ensure a unitary representational relationship. As such the convergence is required to ensure that a referent must mean only one thing within the representational structure. If a referent were to have multiple possible meanings, then in order to communicate these multiple representations would be required. In other words that which is represented must describe only one phenomenon.

The multiplication of representations is not only detrimental to the performance of a representational system, but it is also practically impossible. As a representational system becomes exponentially increasing the representational relationship breaks down as the infinite heterogeneity of representations strips representation of its utility as a communicative tool. A simpler way to explain this is using the example of language. For language, populations share a vocabulary cognisant that words convey to a lesser or greater extent some part of the meaning to a listener – while at the same time accepting that the listener's understanding of the concept may differ somewhat from their own or that the word may only partially describe the phenomena as described by the speaker. In this case some information is wilfully discarded in order to ensure communication. In order to ensure perfect communication the speaker could make up a new word to describe their experience more exactly – but this word would convey no meaning to the listener unless they shared the speaker's encoding and experience of the word. The problem thus occurs that when the speaker tries to convey an experience for which a word is an imperfect description that a new word is required or information will be lost. Quickly each person would require an individual language but would have no means to communicate, and so to prevent this some loss is accepted in order to limit the size of the language. This practical limitation of a representational system for mapping the infinite heterogeneity of existence, gives rise to the convergence of meanings. A converged understanding of concepts is required in order to limit the possibility and existence of an infinity of referents. In the case of a representational system multiplicity means either inefficiency or noise.

The importance of understanding the information theory of representational systems is rooted in the possibilities of a total system of representation with which to describe the world. As we saw in *Section 2.2.1*, the history of measurement and the development into the expanded notions of computation and data that exist in contemporary society, has at its core an attempt to map and understand the world in its entirety. Central to these attempts are claims towards an objective science that would see the phenomena of the world as they are. Unaffected by the vagaries of subjectivity, the mapping of the world is a project whose aim is a single and unified truth. The challenges faced by this attempt to map the world, such as those discussed in *Section 2.3* can be viewed through this information theoretic lens. In order for a model to be complete, consistent, and to communicate, it would have to accept the limitation of subjectivity. As the information theory of Shannon shows an information system is limited in the amount of information it can convey by the number of possible symbols or symbol combinations it can employ. In the mapping of the world it is possible to describe the implication succinctly. In order to create a functional system of representation to describe the world, the subjectivity of different perspectives must be converged to a universal understanding. Phenomena must be thought of through their representational terms. Whilst it may seem that the information theory of representations might have a limited scope by which it could alter our understanding of the world, in *Section 4.2* we have seen how, in fact, this convergence of the understanding of existence is already taking place.

In signal processing the digitization process turns continuous signals into discrete values representable within binary structures. A curve is sampled at points upon its length to create discrete values representable as finite numbers. The digitisation of an analogue signal thus approximates the subtle differences between these finite points as being equal to a known finite point. In the information theory of contemporary society a representational system for mapping the world performs the same process. The understanding of a phenomenon is reduced to the nearest finite representation that can be encoded within a universal ontology. This digitization process is the same as that we have seen, but spoken about in other terms in the previous parts of this chapter – in the coordination of the universal clock, the relation to the affects of bodily sensation through data and to the sharing of an ontology that we have identified as central to the function of a representational system. The convergence of the understanding of phenomena from the subjective to the universal takes place within the context of this digitization. Within the context of a universal system of representation we can suggest that the smooth and incremental changes that mark our subjective understandings of the world become replaced by the external orderings of a representational system.

It is possible to think of the representational convergence, the filtering out of non-representable difference in phenomena as noise, as an optimisation of the representational system with which we describe the world. Optimisation, a term most familiar in mathematics, engineering and more recently in management, is the process of making the best or most effective use of a resource. In the context of a representational system in which it is impossible to display the infinite heterogeneity of referents it is possible to think of optimisation as the selective process of deciding what to represent and what remains representable. In order to maintain the functioning of the system some process of discrimination must take place that will determine the representational structure. This process can be thought of as a process of optimisation. Optimisation, it is possible to suggest is an inherently political process in which a choice must be made to select certain features over others. The decision as to what feature of a system is to be selected for maximisation is called the objective function. In the representational systems of contemporary society, and as we have seen as central to the functioning of any representational system, the maximisation of communication requires the minimization of subjectivity.

In the information theoretic of contemporary society it is possible to suggest that the need to converge understandings of phenomena within a universal ontology serves the function of optimising computability. In order to create a map of existence that can be understood and manipulated by human and machine actors equally, it is necessary to alter understanding of the world in such a way that only knowledge that is consistent with the requirements of computation exist. We have seen in the previous section the ways in which this process takes place at the individual level. The selection of criteria from the perspective of the measurer for the encoding of knowledge has, as we have seen, a political function. The exclusion of knowledge, which is not or cannot be accounted for in the representational system acts as one form of subtraction from total knowledge. In addition, however, it possible to suggest, following on from the discussion in *Section 2.3*, that type of knowledges that are included within the universal representational system reflect the knowledge of a limited subset of society to whom knowledge authority is granted. As such the convergence of subjective knowledge towards common knowledge tends towards the convergence of individual and alternate knowledges towards the dominant understanding. In this way it is possible to suggest that the move towards an increasingly representational construction of society requires and understanding of which forms of knowledge dominate in the production of universally accepted ways of representing phenomena.

4.4 Conclusion – A Map whose Size was the Empire

From the outset, this thesis has set out to develop ways to understand an increasingly computationally constructed society. In order to do so the early chapters of this thesis developed an understanding of computation that was based around the transmission and manipulation of abstractions in place of those real entities to which they pertained. Having surveyed the work of artists and theorists who have engaged with questions of computation in society it has been possible to suggest that this abstract representational underpinning for computation has gone largely unnoticed or unexamined. As such it as been necessary to show how a logic of computation has, and continues to, increasingly permeate across almost all areas of society. In the first section of this chapter what has been shown is that not only are representational structures employed within society as a way of describing phenomena, but as this practice occurs increasingly the phenomena in question come to be conceived of in terms of abstraction. In *4.2.1 The Universal Clock* what was shown was, that as an abstract system for the representation of time came into being, what became important was not an understanding of time itself, but rather knowledge of and understanding of the representational system of time. As such it is possible to suggest that the abstraction has become the primary site of engagement with the phenomena of time. In fact, it can be suggested, as Mumford does that universal clock time produces our understanding of time. An adherence to the ontology of clock time, it can be proposed, has become more important than the individual's subjective experience of time.

In the following two sections the tendency that was observed in the discussion of time was traced across broad areas of activity, in *4.2.2 The Representational Economy* and *4.2.3 The Abstracted Being*. From the examples given throughout these sections what can be seen is that there is a broad tendency to increasingly deal with abstract representations in place of real entities. Further to this it is possible to identify a trend wherein not only are the abstractions becoming a primary way in which certain phenomena are conceived but there is also a conflation of the abstract and the real. This convergence between real and abstract can be seen clearly in the example of cyber-terrorism where individuals express terror in relation to the potential risk to abstraction of themselves. It can be suggested that these examples highlight a convergence in which the real and abstract become converged into a supra-individual subject composed of the combined real and abstract components. In other words, it can be suggested the logic of computation that is evident across society reduces the distance between the abstraction and the real such that existence in the real domain becomes a function of visibility in the abstract domain.

Having explored examples of the current state of development of this tendency towards an increasingly abstracted construction of society it is necessary to try and project in some way the development of this tendency. Rather than try to predict future outcomes based on historical trajectories the second part of this chapter has attempted to examine the mechanisms through which a logic of computation reproduces itself. In doing so this section has examined how the basic functions of a representational system give rise to the need to create a universal ontology to describe the world. In particular what *4.3.1 Representational Knowing in the Human and the Machine* examines is that in order to act as a form of communication between a heterotic assemblage of human and machine actors computation requires the existence of a strictly encoded ontology with which to describe phenomena. This requirement gives rise to the need for a coordination of the understanding of phenomena between actors such that the encoding and decoding relationships between abstract and real domains can produce meaning. In *4.3.3 The Information Theory of Contemporary Society* what we see is that in order to try and ensure the functioning of this communication between entities the removal of individual subjectivities is required if communications are to be maintained. It is possible to conclude from the above that the understanding of the world through forms of data requires that individual reconceptualise phenomena in common terms. In other word, in order that we can have a functioning model of the world that can be operated on by computation we must replace our subjective understanding of a phenomenon with a strictly encoded and universally accepted definition. This effect can be seen in the case of the sexual tracking apps described in *4.2.3 The Abstracted Being* where in order for the application to compute the users sexual activity the user is faced with the ontological question of what constitutes sex within the terms dictated by the data structure. What we have also seen is is that the converged understanding of phenomena exerts a political function inasmuch as the results of these ontological definition display the challenges and struggles toward knowledge authority that we saw throughout *2.3 Partial Perspectives*.

Accepting that the emergent logic of computation requires the creation of a universal and coordinated ontology with which to describe the world, *4.3.2 Perception, Affect and Memory* examines the relationship between the technologies with which the world is described and perceived. By examining Bergson's interacting model of memory and perception it is possible to suggest that the increased interaction with the representational technologies of computation gives rise to subjects whose reality is increasingly informed by and developed through representational knowledge. It is therefore possible to suggest that this reciprocal engine through which representational knowledge produces representational subjects who in turn produce further representational knowledge acts to drive the development of an increasingly computationally constructed society. It is also possible to suggest that the forms of knowledge such as affective and embodied knowledge that are incompatible with the representational structures of computation become diminished. In this way we can suggest that computation acts to influence the future direction of knowing and being by altering the field of virtuals, in other words computation not only impacts on what happens in the future, but what can happen.

What is presented within this chapter therefore raises an important question as to how we develop terms for understanding a society that is increasingly constructed through computation and computational knowledge. What this section proposes is that the development of a computational model of society proposes a challenge to the existence of a heterogeneity of subjective understandings of the world developed through the unstructured transmission of affect. In other words, the convergence of the ways of understanding phenomena into a common ontology proposes to limit the possibility for the creation of new forms of knowledge and understanding that are outside of this way of knowing. Further to this, as the development of a universal ontology involves the selection of dominant perspectives, understanding the development of computation becomes a fundamental part of political critique. As such the ways in which we create the abstract representations of computation, and the way in which we understand that which can and cannot be measured, must also become a central part of contemporary critique if we are to generate meaningful understanding of an increasingly computational word.

5 Unfolding and Entanglement

What counts in the long run is the "use" one makes of a theory....We must start from existing practices in order to retrace the fundamental flaws. - Felix Guattari

5.1 Introduction

This chapter proposes art practice as a way of communicating which encourages subjectivity and difference and thus is a critical tool in understanding the implications of a society increasingly mediated by computation. To do so the chapter explores the concept of multiplicity and in particular the difference between what are described as continuous and discrete multiplicities in order to suggest art practice as a form of open-ended communication that requires difference for the production of new knowledge. Thus this chapter suggest art practice as an essential tool in understanding the implications of living in an increasingly computational world.

Throughout this thesis we have examined a trend towards the convergence of being with its representation. We have seen (in *Section 4.2*) how, across diverse areas of society, there is an increasing tendency to interact with the abstract in place of the real. In addition (in *Section 4.3*) we have examined the mechanism by which this trend reproduces itself. We have seen how the strictly encoded representations of computational systems require the sharing of an ontology between individuals and machines, and we have seen how in order to communicate these representations must abandon subjective and affective knowledges. This marks a change from a regime in which the production of new knowledge exists in the subjective interaction of affected and affecting bodies to one governed by the communication of existing knowledge held within the universal ontology. As such the possibility for subjective knowledges and subjective understandings is reduced through a removal of the unstructured affective component of knowledge. The event or thing no longer operates as an affecting body but exists as a totalised representation-object. If we accept that the creation of new knowledge requires the existence of difference then it remains to develop ways to produce new knowledge in opposition to the effects of this convergence. In this chapter we will examine the creation of subjective knowledge as a way to understand the impact of an increasingly computational society at an individual and subjective level.

The convergence between representation and being exists in a timeline that, as we have seen in *Section 4.2*, stretches back through human history and that projects itself into the indeterminate distance. However, while we have identified within this convergence the seed of its reciprocation, our position at any point on this timeline in which individual subjectivity remains possible grants to us the agency with which to influence this progression. In this chapter we will examine how art practice exists as a way of creating subjective knowledges that are dynamic and open and that operate in the realm of affect.

In this chapter we will develop a way to think of art practice as a type of communication that produces new knowledge. It is not suggested that art practice is limited to activities that operate with certain materials or within certain contexts. Instead it suggests art practice as a form of communication that is unstructured and requires for its completion the production of subjective knowledge. Here, art practice will be discussed in the context of a logic of computational representation, however, this understanding of art practices is not limited to the response to computation. This discussion should prove worthwhile regardless of our position on a timeline towards any number of possible technological futures. There is a cartoon from *USA Today* that shows a group of scientists at a conference discussing climate change - the speaker points the audience towards the benefits of climate action: energy independence, preservation of rainforests, less pollution, better health, etc., one member of the audience responds saying, ‘What if it is all a big hoax and we create a better world for nothing?’ (Figure 5.1). And so, in this section we will explore a methodology for communication that is non-representational, that pays an ethical attention to the subjectivity of the receiver and acknowledges the different ontologies with which we each encode the world. In doing so, regardless of our position in relation to the development of specific technologies, or along the process of convergence that may lead to an endpoint such as that speculated in the fiction with which the thesis began, these practices, it is hoped, may prove beneficial.

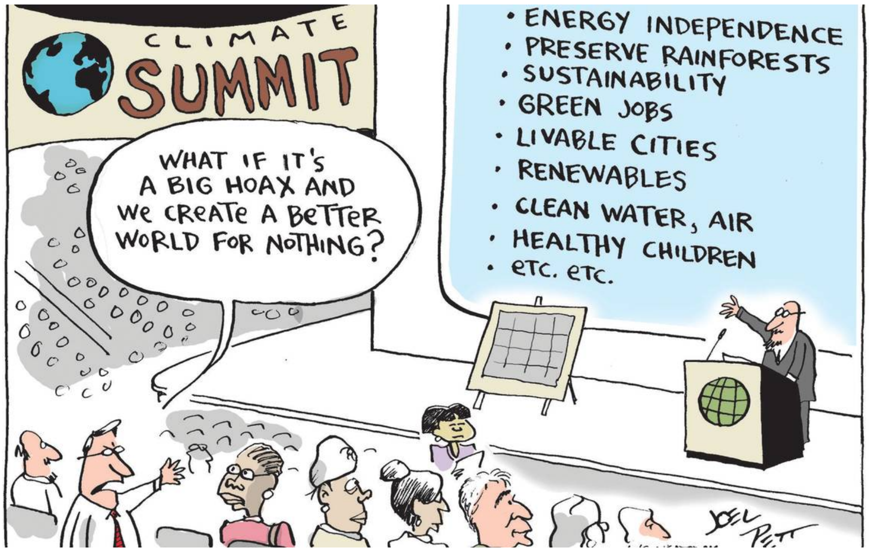


Figure 5.1 Climate Summit. **(**Pett 2009**)**. Printed Cartoon

In this chapter we examine the possibilities of affective knowledge creation through art practice using Bergson's philosophical concept of multiplicity that is developed by, amongst others, Deleuze and Guattari. The chapter examines the difference between Bergson's understanding of continuous and discrete *multiplicity* as a way of understanding the ways in which an art object can function within the wider context of an increasingly representational understanding of contemporary society. In *5.2 Unfolding Multiplicities* the chapter develops an understanding of an art object or art practice that is defined, not through specific activities, but through its intention and its relationship to subjectivity. In doing so the chapter positions art practice as the production of new forms of knowledge that exist in contrast to that which can be easily contained within the representational structures of a computational society. In the following section, *5.3 Art and the Entanglement of Subjectivities* we will see how this understanding is employed with respect to computation and how the art produces new knowledge through the interaction of differing subjects.

5.2 Unfolding Multiplicities

As we saw in *Chapter 4* the logic of computation collapses the gap between the real and its abstract representation. At the same time, it tends towards a point in which the knowledge of phenomena becomes contained within a single unified ontology. In other words, computation converges different subjective understandings of phenomena towards a single universal understanding. In the logic of computation material and its meaning thus become coextensive. The material world becomes strictly encoded in its representation, its relationship to other entities mapped out within a unified ontology. If computation converges our understanding of the world into unified terms, then its counterpoint is a way of thinking that expands the understanding of phenomena in a way that creates divergent and multiple understandings. Thinking in terms of multiplicities is an attempt to open up the subjective and different possibilities with which the world can be experienced and described.

To think of the world through the concept of multiplicity is to consider it as a structure across which infinite and heterogeneous paths and connections are not only possible but are always active. To do so requires foregoing thinking of the world as defined by a top-down systems architecture, described with a defined taxonomy of connections determined, and determinable from some objective position. Instead, thinking of the world as being a multiplicity, and being composed of multiplicities, is a way of thinking of it as a multi-dimensional space in which its geometric rules are differently defined with respect to position within it. The idea of multiplicity is central to the work of Bergson and is further developed by Deleuze and Guattari. A multiplicity in these terms can be thought of as, ‘a complex structure that does not reference a prior unity’ (Roffe, in Parr 2010, 181). In other words, we can say that a multiplicity is that which does not require for its completeness definition from some higher order but in which its completeness is determined differentially by its position in relation to other entities.

In thinking of the world as composed of multiplicities in which knowledges and material have situated meanings and perspectives rather than transcendent ones, we must assume that all constructs as being multiplicities of some degree. This approach is that of Riemann (2016), Bergson (2001), and Deleuze and Guattari (1987). At the same time, however, we can also suggest that the convergence of different subjectivities towards a single universal understanding of the world presents itself as the eradication of this view of the world – the ontological singularity it can be suggested seems to be the end, or the end of possibility for seeing the world as composed of multiplicities. How then, if the world is composed of multiplicities can the convergence towards a single ontology take place? It would seem that the creation of multiplicities of any form is not in itself sufficient action to resist a trend towards an increasingly representational way of understanding the world. In other words, if the world is formed of multiplicities and there exists a convergence of representation and being, then the existence of multiplicities themselves is not a sufficient means of resisting this convergence. This may seem obvious – as we saw in *Section 4.2* the convergence is the overlaying of ontologies such that the world is constructed in a form that is no longer made of multiple meaning but of universal ones, no longer a self-extensive multiplicity but requiring a transcendent ontology. As such, it would appear that thinking of the world as composed of multiplicities does not offer us any particular tools in addressing questions of contemporary computation.

Riemann, Bergson and Deleuze, however, propose and identify two different types of multiplicity, albeit with slight differences in terms, those which are discrete (quantitative) and those which are continuous (qualitative). If we examine these two types of multiplicities it becomes possible to suggest that their differences alter significantly their relationship to computation and convergence. In doing so we can avoid the claim that the concept of multiplicity is employed only when it is productive for our discussion. Deleuze and Bergson describe discrete and continuous multiplicities as differing in their ordering of the world and in their relation to space and to perception. A discrete multiplicity Deleuze notes, drawing on Bergson, 'is represented by space: It is a multiplicity of exteriority, of simultaneity, of juxtaposition, of order, of quantitative differentiation' (1991, 38). On the other hand continuous multiplicity 'appears in pure duration: It is an internal multiplicity of succession, of fusion, of organization, of heterogeneity, of qualitative discrimination, or of difference in kind; it is a virtual and continuous multiplicity that cannot be reduced to numbers' (ibid). In this differentiation continuous and discrete multiplicities differ in their relationship to boundedness, perception and sensation, and fundamentally to the possibilities of their existence within a system of representation.

These different concepts of multiplicity are not entirely intuitive and so it is necessary to explore them in more detail. Riemann, who developed the original mathematical model of multiplicity (for which he used the term *Mannigfaltigkei*t, translated as alternatively as manifold or manifoldness), in fact notes in his initial description that,

> *Notions whose specialisations form a discrete manifoldness are so common that at least in the cultivated languages any things being given it is always possible to find a notion in which they are included. (Hence mathematicians might unhesitatingly found the theory of discrete magnitudes upon the postulate that certain given things are to be regarded as equivalent) (2016, 32)*

In other words, we can suggest that discrete multiplicities are those things that come easily to our mind and measure. They are those that, bounded in discrete quantities, are easily perceptible and compartmentalisable as discrete entitles. Continuous multiplicities on the other hand he notes are not only harder to conceive but that,

> *so few and far between are the occasions for forming notions whose specialisations make up a continuous manifoldness, that the only simple notions whose specialisations form a multiply extended manifoldness are the positions of perceived objects and colours. More frequent occasions for the creation and development of these notions occur first in the higher mathematic (ibid).*

For Riemann, whose concern was in the foundations of geometry, continuous multiplicities therefore represented those elements that could not be counted with objective certainty, which were expressed by quanta, defined only by their relation to other elements of the same order (Riemann 2016, 32). Crucially, what Riemann proposes is that the quantification of surface properties as discrete requires an additional structure beyond the definition of the manifold itself. In more simple terms, Riemann identifies that within a manifold it is possible only to describe qualitative aspects such as position without recourse to an additional metric structure or by positioning the manifold within a higher dimensional space. A discrete manifold's description therefore is extensive, requiring for their definition some outside element, whereas continuous properties are intensive.

The conceptual foundations from which Bergson, Deleuze and Guattari draw their idea of multiplicity are thus inherently mathematical and are founded in geometry and topology. Nevertheless, they extend the concept of multiplicity beyond its role as a geometric concept into metaphysics. In doing so it is required to extend an understanding beyond that which is possible in Riemann's description. For Bergson the distinction between the discrete and the continuous is also based on the possibility of quantification. In doing so Bergson argues that discrete multiplicities are those that are represented by space, that find their quantification in geometric order through the process of their objectification. In this way, we can suggest that as with Riemann the requirement of quantification are related to the existence of a higher order system with which entities can be described On the other hand, a continuous multiplicity, he describes, cannot be regarded as numerical but is based on continuous change in the subject in terms of duration (Bergson 2001).

Deleuze further extends this idea in *Bergsonism*, he notes, 'Bergson moves toward a distinction between two major types of multiplicities, the one discrete or discontinuous, the other continuous, the one spatial and the other temporal, the one actual, the other virtual' (1991, 177). He goes on to describe how, '[discrete multiplicities] contain the principle of their own metrics (the measure of one of their parts being given by the number of elements they contain). [Continuous multiplicities] found a metrical principle in something else, even if only in phenomena unfolding in them or in the forces acting on them' (ibid, 39). As such Deleuze highlights the difference between them as being based on their boundedness as well as their relationship to measure. Roffe summarises

> *Deleuze notes first of all that there are two kinds of multiplicity in Bergson: extensive numerical multiplicities and continuous intensive multiplicities. The first of these characterises space for Bergson; and the second, time. The difference between extensive and intensive is perhaps the most important point here. In contrast to space, which can be divided up into parts (this is why it is called numerical), intensive multiplicity cannot be divided up without changing in nature.* (in Parr 2010, 181)

As such it can be suggested that Deleuze's distinction between extensive and intensive multiplicity describes the possibility by which a multiplicity can be defined from within or from without.

From these accounts it is possible to see how a discrete multiplicity, that is one that is founded in quantification, is easily conceived within the structures of measurement and representation. A continuous multiplicity is one where the distinction between values varies not within Euclidian or Cartesian space of discrete numbers but through changes of intensity at a given point. In other words, a continuous multiplicity is one which operates in the field of time rather than geometry and which is governed by change in itself as subject rather than in its external order as object. It is possible to suggest that a continuous multiplicity is exactly the sort of unrepresentational knowledge that sits in contrast to the representational knowledge of computation. A continuous multiplicity it can be suggested is that whose meaning cannot be described from the outside through its representation, but rather which produces knowledge though interaction of affected and affecting bodies. As Roffe notes, ‘any alteration to an intensive multiplicity means a total change in its nature – a change in its intensive state. This is important for Deleuze because it means that there is no essence of particular multiplicities which can remain unaffected by encounters with others (ibid, 181-2)’.

It is possible to relate this thinking of multiplicities to the terms of the representational knowledge that is central to computation. The concept of a discrete multiplicity, we can suggest, is consistent with the ordering and representational practices of computation. In order for a representational system to communicate, as we have already seen, there is the requirement for its description within a shared ontology. Beyond this, it can be suggested that this involves thinking of objects as discrete, of conceiving of them as quantifiable, objectifying them. What we have seen within *Chapter 4*, however, is that as a logic of computation expands throughout society those intensive properties that we may think of as continuous multiplicities seem to increasingly also become thought of in discrete terms. This, Bergson relates to science’s ‘irresistible tendency to set up a material universe that is discontinuous, composed of bodies which have clearly defined outlines and change their place, that is, their relation with each other' (1991, 197). What it is possible to suggest is that the logic of computation acts to describe continuous multiplicities as discrete in order that they can be communicated within a system of representation. Bergson in fact describes this process of 'symbolical representation' (2001, 100-1) as a necessary requirement of attempting to quantify that which is continuous. He describes this as thinking in geometric rather than durational terms. In other words, in order to quantify that which is continuous, he suggests, that we must conceive of it in simultaneous terms that allow us to hold them in mind together.

Recalling Riemann, in order to quantify properties within a continuous space an additional structure or higher dimensional space is required. If, as Deleuze and Bergson do, we extend this notion beyond its mathematical description of geometry we can think of geometric space as of a higher dimension than duration. Doing so we can propose that the describing continuous multiplicities within discrete terms requires the application of a metric or higher dimension that is extensive to the space in which the multiplicity operates. In other words, we can suggest that the process of representation requires a setting apart of our position from that which is represented, in order to describe the world we must set ourselves as outside of it rather than as situated and bounded in it. Bergson in fact suggest that the ability to describe with metrics through which the entity can be broken down is exactly what is called objectivity – to be able to break a unity into parts with which it can be represented, as opposed to being able to know it as a whole through our subjectivity (2001, 99). The representation of the world within computation can thus be suggested as applying a metric function to the continuous multiplicities of existence. Thinking of this it is worthwhile recalling from *Section 2.2.1* the work of Gödel in which he highlights the impossibility of any attempt to describe with incomplete tools a universe that appears complete. However, what *Section 4.2* might suggest is that the success of a computation might be to redefine existence within the dimensions of its metrics rather than attempting to expand its metrics in such a way as to account for the continuities of existence. Finally, it might be possible to suggest that continuous multiplicities are thus those things that resist representation – that they can be known only subjectively.

5.3 Art and the Entanglement of Subjectivities

To discuss techniques and strategies that contribute to a creation of non-representational knowledges it is necessary to discuss how such practices differ from the representational knowledge structures of computation. It is also necessary to group those practices under some term that will allow us to access them in unison with each other. To do this we will call these practices art. It is not possible to do so without describing in some way what it means to use this term – not least in the acknowledgement of debates which have happened in western philosophy (Kant 2000, §44) (Schopenhauer 2010; Schopenhauer 1966) (Dewey 1980) (Buchenau 2013) back to Grecian debates on *techne* and *episteme* (Plato 1991) and undoubtedly further in those other philosophies that stretch over and span the history of humanity. At the same time, it is not the aim of this thesis to give a rigorous definition of all that constitutes "what art is". Nor is it the intention to develop a taxonomy that would stand up against claims that art is something that does not fit within the categorisation, or of something that fits within the categorisation is not art. Conveniently it is also not necessary to do so; instead we will use a definition of art that is held as intrinsic to the discussion itself. In this context art will be defined as - that which does what we will describe art as doing - and anything that operates in that way will thus be art. While this is tautological it is not pointless. It allows the discussion of something based on its operation, meanwhile allowing it to evade the problem of being collapsed in its attempt to define too strictly its field of operation. As such art is not limited to the use of particular materials, the application of particular skills or the presentation within particular environments or contexts. Neither does it require that a person in a particular position with respect to society or institutions makes it art. Instead, art, as we will define it, is a set of practices that create the possibility for the production of subjectivity – it is an intention to communicate something from one person to another without explicit definition of what that thing should be. It is useful to think of art then not in terms of objects, but in terms of practices or processes. Instead of talking about what art *is* it is useful to talk about what art *does*. We must also think of it, however, in respect of its relationship to that which we have identified as the logic of computation. What will quickly become evident is that art exists as a political action or choice that offers alternate possibilities for ethical communication.

To understand the relationship between art in this way and multiplicity requires thinking about our relationship to the possible and the virtual. The virtual sits in some possible future ready to be actualised – to be brought in to existence – or which will, not having been actualised, disappear as unrealised possibles. What Bergson and Deleuze suggest, however, is that, 'the objective is that which has no virtualitv — whether realized or not, whether possible or real, everything is actual in the objective' (Deleuze 1991 41). In other words, it is possible to suggest that in a world described objectively there is no more to be communicated. Relating this to the discussion of discrete multiplicities what we can suggest is that by defining a metric by which to make discrete continuous space, we remove the possibility for the space to produce other actuals. As discussed in *Section 4.3.2* the virtual is actualised by the technologies that are available to us to bring it into existence. In other words, the virtual is actualised through our relationship to the world, our subjectivity and the tools we have for understanding it. As we examined in *Section 5.2* the technologies of computation require us to place ourselves in a transcendent and disinterested position in order to *see* that which we measure as separate from ourselves such that it can be communicated as a representation. To think in terms of continuous multiplicities is to attempt to see from the position we occupy – a strong objectivity – and in doing so to acknowledge the existence of other positions. In other words, it is to accept the position from where we actualise the world, and to accept that it *is* a position within a continuously variable field.

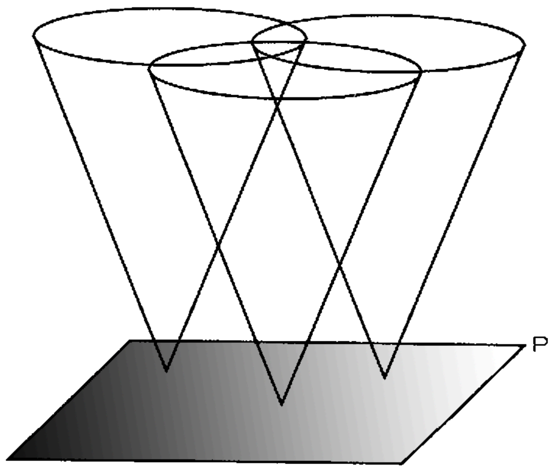


Figure 5.2 An altered version of Bergson's cone in which the alternate subjectivities of each position expose the tip of the cone to different parts of the plane of existence.

To think of our position as grounded in this way is to admit the possibility of other positions and to accept the world as consisting of multiplicities. In other words, it is to accept that the meaning produced is not universal or singular but that from each position different meanings of the world are actualised. If we accept that we occupy a single position, then the admission of other perspectives is also the admission that other virtuals could be brought into existence through their interaction with different subjectivities. It is possible to suggest that understanding our position as grounded in subjectivity and admitting the existence of other subjectivities we create the possibility of seeing our subjectivity as open to change, rather than as fixed. This relationship to the virtual and its actualisation can be thought of in terms of Bergson's production of subjectivity that we saw in *Section 4.3.2*. Here, however, the difference in our position (subjectivity) exposes us to the plane of existence in different ways (Figure 5.2). In this way existence presents itself as continuously multiple – unfolded through different subjectivities – rather than as a process to be described and understood objectively.

If, as was discussed in the previous section, continuous multiplicities are those that evade representation it still remains to describe that which we call art. In doing so, it can be suggested that art operates in the domain of continuous multiplicity and as the creator of multiplicities. To do this, it is necessary to recall from *Section 4.3.2* the discussion of affect and in particular the idea of communicating without representation. Recalling Shouse's description that the 'power of affect lies in the fact that it is unformed and unstructured (abstract)', and that, 'it is affect's "abstractivity" that makes it transmittable', is central to the way in which art can communicate without representation. Representation, as we have discussed, requires the sharing of an ontology in order that a message can be encoded, sent, received and decoded. Unrepresentational communication it can be suggested is communication in which the message cannot be constituted within the ontology of either the sender or receiver. Instead it exists in the space of interaction between these elements that is generated through their difference. As such it is not possible to conceive of this form of communication in the form of messages as constituted within the systems of information theory discussed in *Section 4.3.3.* That is to say, that whereas messages communicate through the sharing of a system of encoding/decoding relationships (an ontology), affective communication operates through the interaction of that which cannot be shared through a common ontology. Rather it is constituted only by the interaction of two differing ontologies. In other words, it is the portion of communication that occurs between two differing subjectivities.

Before proceeding further with this description of art it is important to state clearly at this point a caveat without which some confusion may occur; namely that this description of art as communication without representation does not preclude the use of representation within art. In fact it is probable that there exists no art which does not include representation in some form or other, whether it is the use of text, the use of convention that refers in some way to previous work, or whether it is the context – institutional or otherwise – in which the work is received. The distinction, however, is that whilst representation may be present within the work representation is not that which makes the work function as art – or more specifically, and perhaps obviously, as unrepresentable communication. One way to think of this may be to think of examples of writing as art, be they poetry, novel or any other form. Here communication of two types is present. At the same time and encapsulated in the same text is both representational communication and unrepresentable affective communication. The representable can be thought of as that part of the language that produces a predictable response in the reader, the understanding of spelling and concept referred to by the word. The unrepresentable can be considered as that part that is indeterminate, the way in which the reader builds the world contained within the text and the way in which their world is reconceived of, having come into contact with the text.

How then does art exist as a form of continuous multiplicity – a form of affective communication? To understand this it is necessary not to think of art as an object that sits in isolation from the world in which it is situated, or in which it is created or received, but to think of art as a process of thinking and acting in the world that is manifest through some material action. That art is often manifest in a material object has in many ways been the source of a confusion that has led to art being thought of as a discrete entity that exists as the end point of a process of creation. Instead, it is useful to think of the art object as a nexus or centre of gravity through which multiple flows enter and out of which multiple flows emanate. To do so is to place the art object as existing during the process of art’s functioning as opposed to antecedent to it. This view conceives art as a process rather than an object. Importantly this process is not bookended at one end by the artist’s moment of creativity and at the other by the finishing of the piece of art and its display. Instead art can be proposed as a way of acting within a field of multiplicities with the beginning of the process no more identifiable than the beginning of a thought. As described by Lyotard's, 'they are not registered by areas, except out of human commodity. Thoughts are clouds. The periphery of thoughts is as immeasurable as the fractal lines of Benoit Mandelbrot' (1988, 5)). Instead it is useful to think of the process of art as the gathering of strands from the multiplicity of existence as experienced through the artist's subjective frame, and gathering them into the material manifestation of the art object or action. In the same way the process's end is equally fractal. It is useful to think of the process not as a singular chain of events – affected and affecting bodies – but as a scattering of flows out of the material into the multiple unfoldings affected bodies of those who perceive it. In this way the art object continues to produce as its flows interact with new subjective bodies. The image of the prism comes to mind or of the endlessly crashing particles of a particle accelerator.

Proposing art in this way is to suggest it as a process that cuts across the structure of representations and creates linkages between rather than along the systemic structuring of knowledge into its classes and ontological categories. O'Sullivan describes this as the interaction of two machines, a "subject-machine" and an "art-machine". The art-machine, he describes, denotes that which is the material containing the processes that are gathered together in its production, whilst the process that emanate from it are the result of its interaction with the subject-machine - the receiver (O'Sullivan 2006, 21-23). That there are infinite subject-machines to interact with gives rise to the unfolding of possibilities that give these outward processes their fractal nature, but also that preclude their existence in representation. For each interaction between these two machines no *a priori* map exists. It is not necessary here to focus too much on the idea of a subject-machine – as we have touched upon it in other terms in our discussions in *Section 4.3.2.* Instead it is useful to speak a little more about the art-machine (art) or the processes that flow into the material action, and then to speak a little about those process that emanate from the interaction of these two machines.

The creation of art, or the processes that lead to the creation of some material event or effect, is an action in itself that is not guaranteed. It finds its basis not only in the subjectivity of the creator, but in the understanding of the process through which art operates as a form of communication. Namely, as a form of communication it requires both an acceptance of the limitation of one's vision with respect to the multiplicity of possible viewpoints, and it requires an understanding of the possibility of one's vision existing from another perspective. This acceptance of difference opens up the possibility of communication without representation and as such the possibility of arts function. In other words, art requires the attempt to communicate without knowing the messages explicit result. Instead it can be suggested as an attempt to communicate that which cannot be defined objectively but which is known wholly through its subjective experience. Communicating in this way it can be suggested is primarily an action grounded in ethics. It is to accept the difference of each subjective understanding, whilst requiring nothing of the receiver with respect to the understanding of the sender. In other words it is to suggest that art as we define it is nothing more than to communicate the portion of experience that is illuminated to ourselves as subjects by instilling them in some material action and allowing this material action to create affects that are no longer tied to our subjective understanding.

The creation of new understanding through the interaction with art is in this respect communication in its most basic form – the interaction of two bodies in the creation of affect. This creation is unbounded in as much as it requires no strict decoding in order to communicate, but it is bound to the event and through this to its creation and therefore to the subjectivity of another. Art then is a technology that is creative in its relation to possibility, which is not to say that art gives an insight into the possibility of seeing differently, but rather by opening a conduit between two subjectivities changes the possibility of that which will be actualised from the virtual. O'Sullivan describes this as such,

> *We might rephrase this and say that whereas the possible names a logic of Being (ontology of stasis), the virtual affirms a logic of becoming (ontology of process)….The virtual, or rather the actualisation of the virtual, is then the creative act – precisely the production, or actualisation, of difference and thus diversity from a pre-existing field of potentialities* (2006, 103).

In other words, art creates other possibles, through the creation of new understanding it draws those possibles that had become frozen in the structured space of representation back into the field of virtuals. It is as such an act of divergence - an unfolding.

Whilst it is tempting to get drawn into the discussion of the work of art, its functioning and its relationship between the subject and its material existence, it is not the focus of this thesis. Rather, as we have stated at the outset the purpose of this thesis is to examine the convergence between representation and being and to try develop some ways to understanding its implications. In other words, the aim of this thesis Is to find out what it means for us as individual subjects and what it means for us as individual subjects connected through a vast multiplicity of social, political, economic, genetic, geographic, chemical, biological, etc. matrices. The length of this list of connections, and the fact that it is perfunctory with respect to the totality of connections, and is always limited in the subjectivity of the individual who describes it makes art the necessary action of this thesis. It is not only that art communicates in a form that is outside of representation that requires art as a mode of investigation in this thesis. It is that art is capable to creating new knowledge that exists before the possibility of its representation – knowledge that is subjective. As such art is the materialisation of ethical communication that allows the possibility of individual and subjective understandings about our relationship with computation. .

It is possible to suggest that the urgency of art practice in the context of contemporary computation is the need to understand the relationship between the map that computation creates and the multiple and subjective territories we inhabit. In this context the creation of subjective and open-ended knowledge offers a tool for expanding the field of virtuals, for making active and multiple the possibilities that have become frozen in the strict encodings of computation.

6 A Momentary Conclusion

To write a conclusion to this text is possible only in the acknowledgement of the thesis in its entirety. As discussed at the outset, this thesis is one of artistic practice and of theory in concert with each other. As such a conclusion here is a sort of coda that signifies the point of departure between the knowledge that is strictly encoded within this thesis – the text – and the knowledge that is generated by this thesis through its interaction with the viewer and its reaction with the context in which it is encountered, altered as it may be from that in which it was written. As was proposed in *Chapter 5 Unfolding and Entanglement* the practice part of this thesis is that part which is most operative in its creation of new knowledge and the text sits as a background and accompaniment to this. Nevertheless, it is important not to eliminate the importance of the text itself, as a study of the contemporary context in which we are all situated and the context in which the practice was made. Thus the reading of the text informs the understanding of the practice differently to its encounter in isolation. As such it is important to conclude the written section, not by trying to find an overarching theory that will stand as proof of the Ontological Singularity's predominance over other futures, but that will highlight the imperative of finding ways to understand the contemporary condition of society and the role of representation in it. In doing this, and in speculating the Ontological Singularity as an endpoint, we are presented with a way of thinking about, and shaping, the future that follows immediately from this present moment.

This text, as best as possible, has identified a trend, or series of trends, that have been gathered together as sharing a possible endpoint. As stated at the outset, to comprehend this endpoint requires a projection towards an imagined future. This future is untethered from our current understanding of knowledge and being in as much as it requires a total reorganisation of both, and of their interrelation. This, however, does not render the exercise impractical or useless, but rather allows us to think about the current state of contemporary technology and its relationship to the possibilities of our future. It is not an attempt to suggest that we are bound by teleology of the present, to remove the agency we have over our future, but rather it is an attempt to use our understandings of the present to help us guide our futures. As such the speculative proposal of the Ontological Singularity is an exercise in thought that creates the possibility for a thinking of an immediate future in a way that is less bounded by the *telos* of the present. The reason for this is that having identified both a trend and an engine of reciprocation that drives it, it is necessary that we examine the alternate possibilities that diverge from it. These possibilities do not exist as a menu of alternates from which one can be chosen, rather they are virtuals that come to be through the possibilities of our present. The virtual requires the existence of multiple possibilities, the existence of multiple ontologies that are situated and created within the individual and the subjective. Imagining these virtual worlds is essential to their creation, and it is for this reason that the practice of this thesis is the creation of new knowledge but also the necessary response to the idea of the Ontological Singularity.

Two of these possible worlds are described by other artists in their response to the practice of this thesis. As outlined in the introduction the final version of this thesis will contain two responses to the practice element of the research. These responses are a form of subjective documentation of the practice element that will be continually available for access through the academic institution.

7 Artist Responses

7.2 A Response by Jessica Foley

Having Failed to Completely Determine a Unit

with which [redacted] might be so Perfectly Measured[1]

(The Precedented Suicide of a Scientific Researcher)

And considering that this will have an impact on my career

in the future and my reputation in the area of [redacted],

my future life will be worse than death and I will be totally in a dilemma.

In order to make up for the fault, I decide to suicide.

I hope you can learn my lessons and don't mess around with [redacted].

We shall never claim too much in [redacted] before we can really achieve it.

I hope this will make a change in this world.

I hope you can keep simple and stay honest in [redacted].

I will bless you in another world [2].

[1] *The Ontological Singularity*, Tom O'Dea

[2] *The Suicide Note of Huixiang Chen*, https://medium.com/@huixiangvoice

7.4 A Response by Dennis McNulty

UNREPRESENTABLE

A Seance for Pierre Méchain (1744 – 1804)

A response

PART 1

I'm standing in the exhibition space and thinking about it from the perspective of Google Maps. Google's European head offices are close-by, so this seems appropriate. Pinch and Zoom. What is at the edges of each frame? What is contained in each frame? What roles have the things contained in the frame played in the history of the area?

Standing outside the exhibition space minutes before, the red bricks of the Enterprise Centre struck me as emblematic of a certain period of construction in Dublin City centre. Since the seventies, red-brick was chosen by architects as way to create a structure that bears some relation to the city's Georgian Heritage. Inside, the chunky materiality of the cable trays resembles conveyor belts. The cables look lonely, one or two of them lying in a space designed for tens, like an aerial shot of a single car on a multi-lane highway. The trays are bolted to the building, to the floor and the walls. They are composed of modular elements which have been designed to be fitted together in a particular way but this particular installation is crafted, hand-made, bespoke, and the trays are fitted to respond to the topology of the exhibition space. They extend through the walls, through rectangular holes which look like they were made for that specific purpose. What's behind there, behind the surface of the walls? Do the cables pass through and connect to some wider network outside the confines of the exhibition space? Is there is anything at all behind there? Is there even a 'behind' at all?

The works are distributed more or less evenly across the space.

Three installation elements are composed of networking components, black nineteen inch server-rack patch bay strips and red ethernet patch cables. Two of these are placed in corners, in the folds of the space. One sits flat in the centre of a wall. They are oriented differently and the patch cables are connected in various permutations in ways which suggest weaving or rope drawings.

Sound-wise, there are synthetic voices – male and female. Computer voices. Digital assistant voices. Text to speech voices. 'Infrastructure cautioning you' voices. Certain words are truncated. If the voices weren't generated by a machine I would say swallowed but machines can't swallow. They're talking about a map.

<computer voice>

> “Inhabitants”

> “Empire”

“Facsimile”

</computer voice>

Diagrams are projected on the floor. There are permutations and combinations here too.

<computer voice>

“Length”

“Temperature”

“Luminous Flux”

</computer voice>

One work, composed of cable trays, envelope-sized screens and cabling, spans a convex corner. Two PCBs also form part of this assemblage. They are etched with texts. One equates movement with freedom. The other mentions “an invariant of nature”, presuming that anything in the universe might be invariant.

The computer voices mispronounce Mechain. I remember that someone once told me that pronunciation is the enemy of the autodidact, that someone who learns everything from books can never be sure how terms or names are to be pronounced. Are these computer voices self-taught? Were they unsupervised in their learning?

When I encounter them, both displays, even though I know they are digital, appear to produce images by means of a slow raster. Each image appears to be wiping downwards like a jpeg loading in Netscape in 1996. The images themselves sizzle onscreen, their colours noisy and scrambled. I'm reminded of dithered bitmaps, the 90s again, the early (for me) internet. The interference, in its foregrounding of the pixel content of the image, has something of analogue TV snow about it. In the image is a man with George Washington hair. I presume this is Mechain though I don't know for sure. There is no list of materials. The exhibition is not 'footnoted' in any conventional sense.

The image's background is wallpapered with a plant-print, rendered in purple and green. Judging by Mechain's skin, these colours are clearly not the original ones. So what are the real colours, the originals? There has been some displacement here, like some scrambling of the RGB values. There is something of the rudimentary Photoshop filter about this effect. It reminds me of a project I worked on years ago where there were problems with the cabling between a keypad and its controller. The ASCII codes got scrambled by the crushed cables causing a partially comprehensible word-salad on the keypad display.

Pierre has what looks like a Maltese Cross pinned to one lapel and he seems to be writing. He holds a book in one hand. A quill is also visible. He is not measuring anything in this image from what I can make out. Maybe he is in the notation phase of his project?

<computer voice>

"The farthest reaches of the Empire"

</computer voice>

It's tricky to read the image of Mechain because the image is almost quartered and offset. Like a vertically rolling analogue TV, the top half is at the bottom and vice-versa. The left-hand-side is at the right and vice-versa. The image's origin point, its lower left-hand corner, is about two thirds of the way across the image from the left and a third of the way down from the top.

There is a gentle snap from the piece on the floor. The X-Y mechanism, the belts pulling it back and forth to generate a shape in the air over the other shifting shape sketched out on the screen. Black on white. I walk over to gaze down a little closer at the screen and I can make out three bits of text.

<dynamic text>

"Tour de Mont Jouy"

"Tour Nord de la Cathedrale"

</dynamic text>

It becomes apparent that the third bit of text is actually a melange of a few others. I wait. The geometric shape onscreen shifts. Various interconnected triangles rearrange themselves. Thin black lines connecting a bunch of dynamic nodes. Each text is attached to a node. As the nodes move, the texts move. Sometimes they overlap. I wait and the text-moire pulls apart and becomes legible.

<dynamic text>

> "Tour de la Citadelle"

> "La Fontaine d'Or"

> *"Laterne du Fort"*

</dynamic text>

I don't recognise any of these place names but I presume they're something to do with Mechain's story, his journey to measure the world, his struggles with triangulation. I am aware that things are still triangulated today, mostly digitally. At CONNECT researchers have worked on a way to locate IoT devices connected to a LoRa network, triangulating them using signal strength measurements.

<computer voice>

> "The entirety of a city"

</computer voice>

The texts onscreen forms composites, like the diagrams projected onto the raw concrete floor close-by. Language overlaps everywhere in this show. I am reading and listening simultaneously. I am looking, bending down standing still, walking back and forth between different elements in the show as they catch my attention. The arrangement of works forces me into a choreography.

The screen on the floor is held in a blue metal framework made from undainty metal channels. Wires are exposed. The feel is 'infrastructural'.

<computer voice>

"Having contented myself that I was not being deceived"

</computer voice>

I return to the server rack elements embedded in the walls. This network technology and the fabric of the building are merged. I notice the way the other work wraps around the corner. You need to be careful not to step on it as you view it. It's awkward and its awkwardness makes me aware of my body. I begin to wonder whether this is a space made for humans to inhabit? In most infrastructural installations (I use the word here in the non-art-gallery sense), humans are secondary to the activity that's taking place and they way things are arranged in the space usually conveys this.

Here, there is an empty space overhead criss-crossed by a skeletal dropped ceiling framework devoid of tiles. The guts of the plenum are visible, the infrastructural bits and bobs which are usually hidden behind the tiles.

<computer voice>

“some ill effects of travel”

</computer voice>

<projected diagram text>

“Luminous Flux”

“Temperature”

</projected diagram text>

Some of the diagrams projected onto the floor contain grids. I look closer and one of the constituent elements in these projected images appears to be composed of an image of a cone sitting on a grid. Arrows are another key element in these composite diagrams. Arrows usually imply dynamics or at the very least, action of some sort. Sometimes these diagram composites overlap inexactly in a way which suggests multiple simultaneous perspectives. Legibility is often an important criteria in the production of a diagram. Here, that doesn't seem to be the case. There's a sense of Bourroughs and Gysin's cut-up technique in these diagrams, of processes of rotation and superimposition applied as a way to extract hidden meanings. At times they are almost Masonic.

<projected diagram text>

"Fig 4."

"B"

"P"

"P"

"S1" (encircled)

"A" (encircled)

"Temperature"

</projected diagram text>

On the floor, drawn in projected light, two intersecting planes define a space strafed by diagonals, by cone-sides, bringing to mind the kinds of quasi-diagrammatic images produced by famous paper architecture practices of the 1960s (Archigram, Superstudio etc.) These images were part diagram, part attempt to represent real space, language inserted into geometry.

<projected diagram text>

“Fig 4.”

“Kg” (encircled)

</projected diagram text>

These interpenetrating cones sometimes suggest potential sculptural forms. Sometimes these are plausible, as in they appear like they might remain stable in real space. Sometimes planes overlap chaotically, screaming at each other and elbowing each other out of the way.

Looking back at the other piece close-by on the floor, the onscreen diagrams are an example of what engineers call graphs – a series of nodes connected together by lines. If this was a network diagram, these lines would indicate interconnectivity. The 'graph' onscreen here is simple by anyone's standards, simple in the sense that it doesn't contain many nodes.

<computer voice>

“Not so fond of cartography”

</computer voice>

In the real world, in structural engineering, triangles are known to be the most stable form, hence the proliferation of trusses. Here, they are constantly moving. This most stable of forms lets us down.

The screen itself is plain. There is no bevel around the edges. A sheet of glass sits atop the LCD/LED plane, offering another plane, one on which things might be worked out. The machine appears to be trying to work something out. Endlessly. Fruitlessly. Caught in a futile activity. Error-ridden. The metal 'pen' is always either behind or in front of the image onscreen. Like real-world planning scenarios, there is latency.

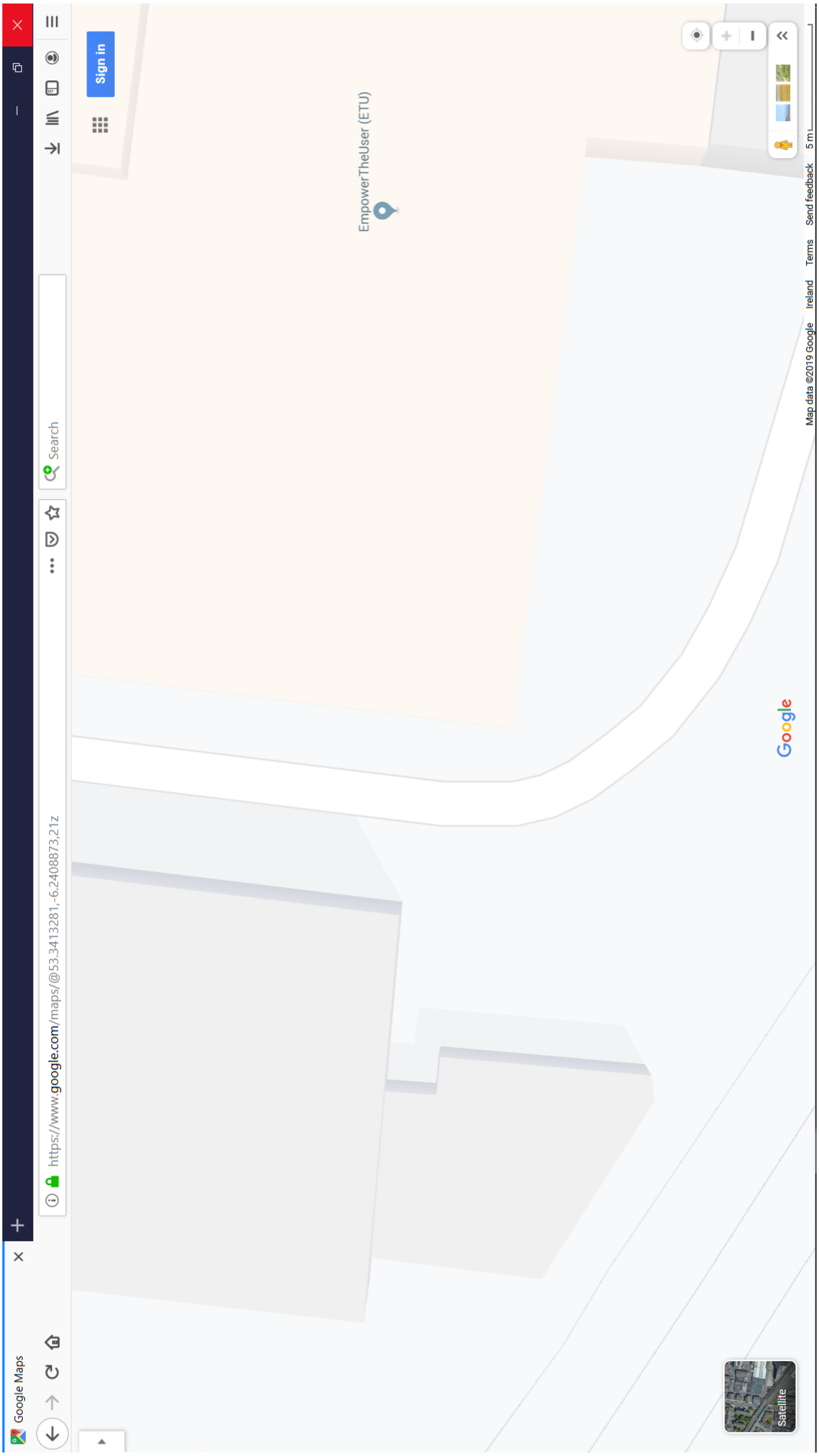
<computer voice>

“... for I saw that no new map of the empire could be drawn that could not be a facsimile of a map of the part”

</computer voice>

Dennis McNulty

PART 2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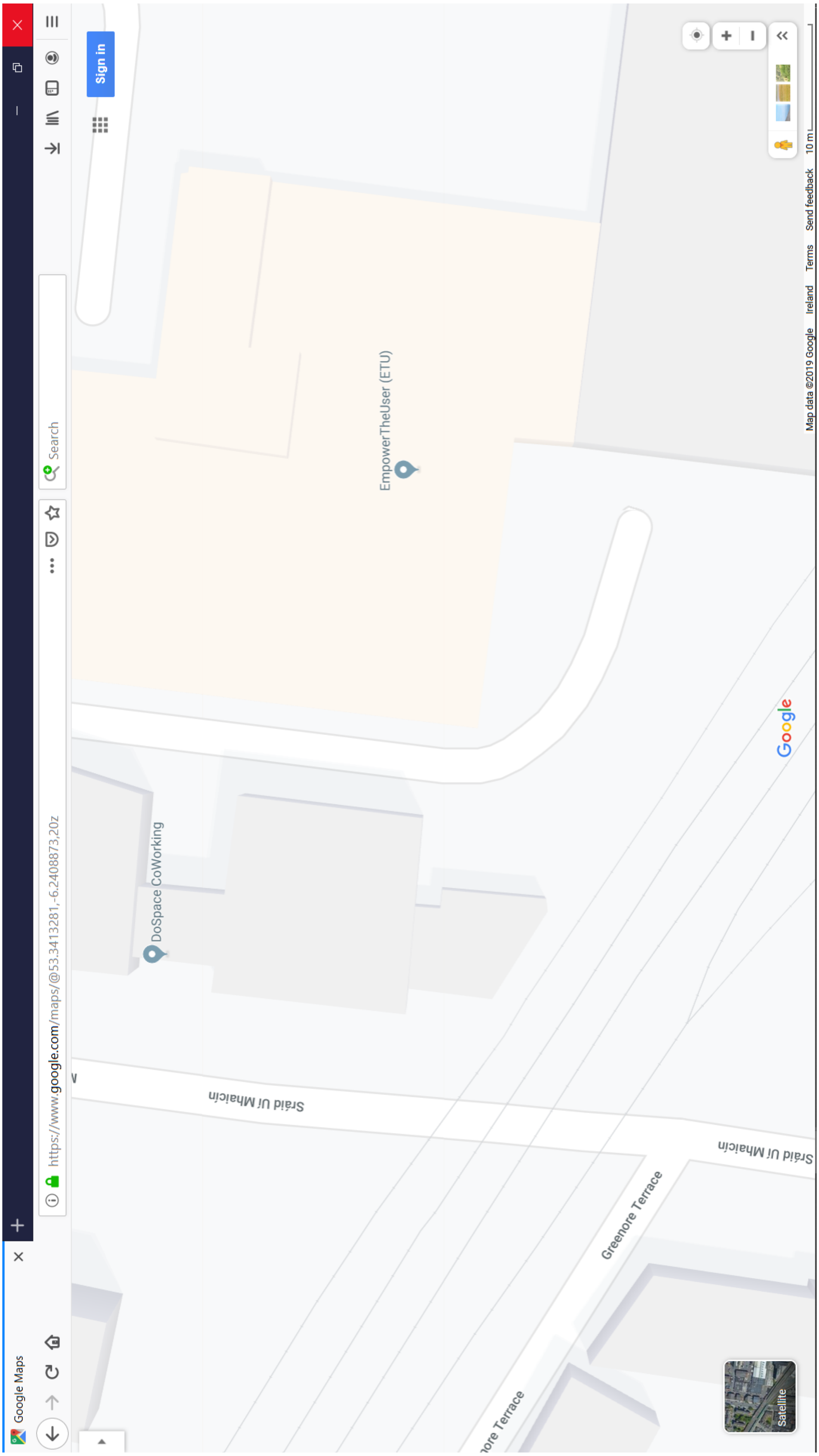
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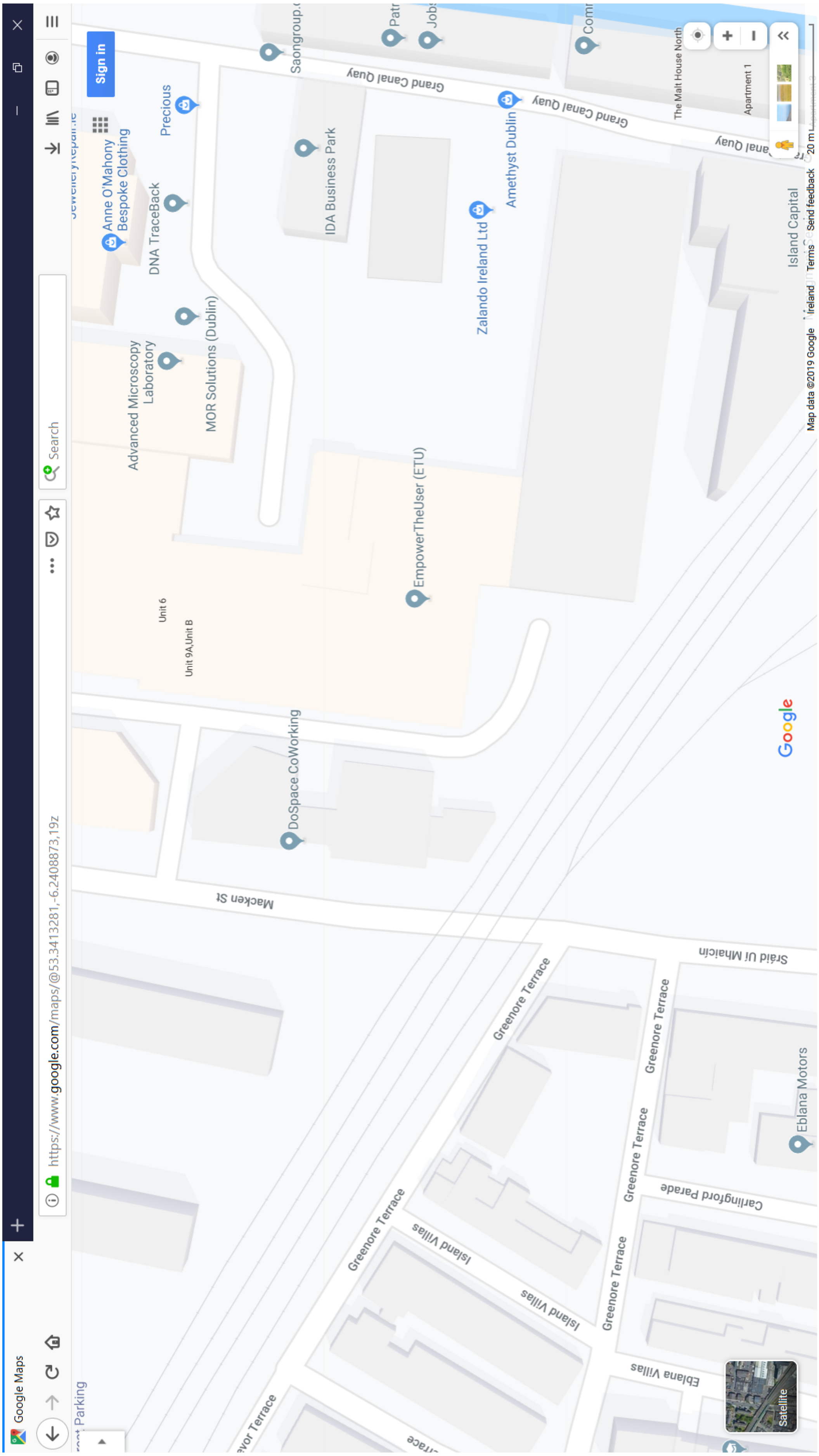

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Zalando Ireland Ltd
Advanced Microscopy Laboratory
MOR Solutions (Dublin)
EmpowerTheUser (ETU)
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Unit 9A,Unit B
DoSpace CoWorking
Macken St
Sráid Uí Mhacín
Greenore Terrace
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Carlingford Parade
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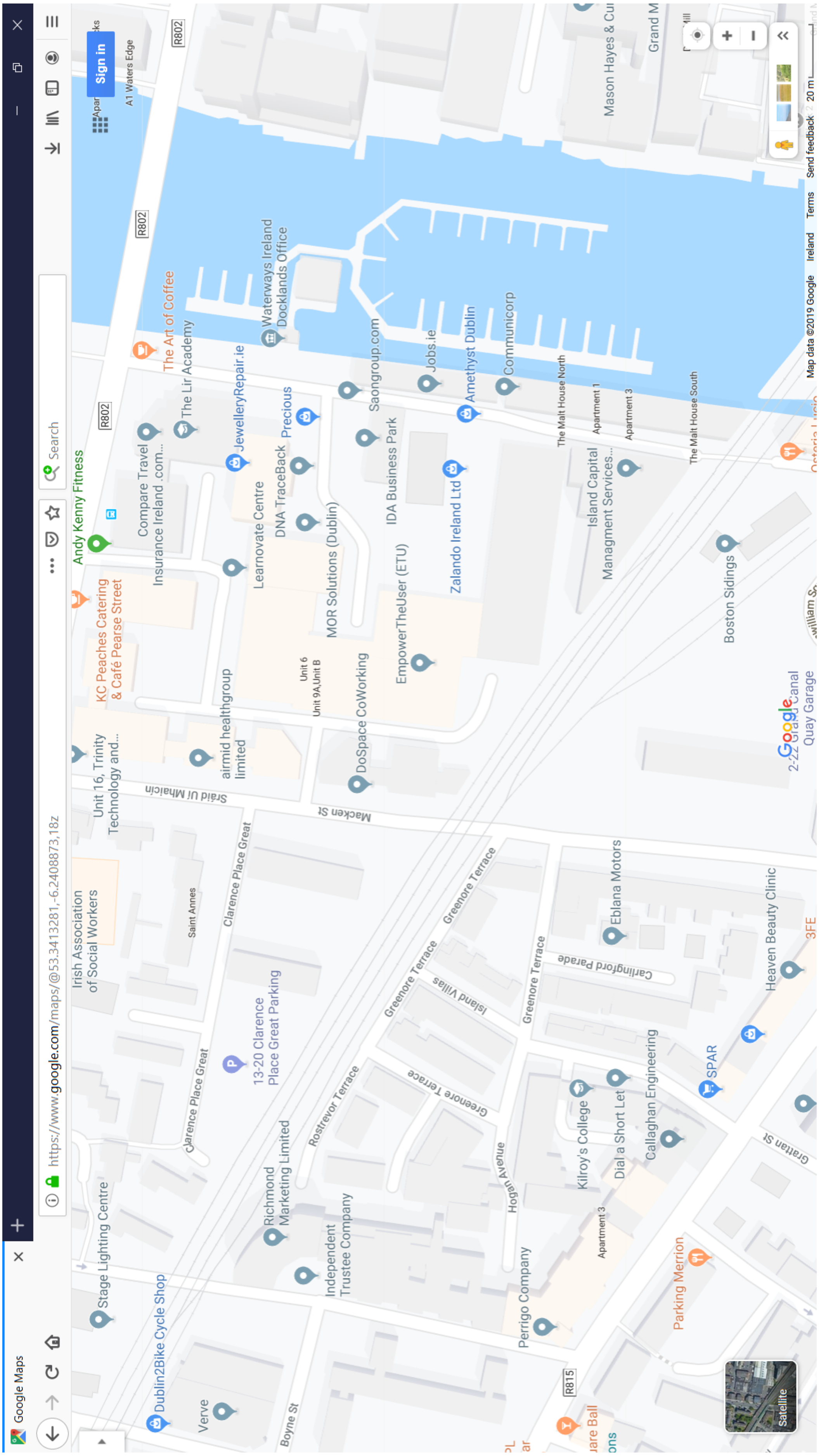
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Waterways Ireland Docklands Office
JewelleryRepair.ie
Learnovate Centre
DNA TraceBack
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Grand Canal Quay Garage
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Sráid Uí Mhaicín
Macken St
Saint Annes
Clarence Place Great
13-20 Clarence Place Great Parking
Greenore Terrace
Island Villas
Eblana Motors
Carrigfoyle Parade
Heaven Beauty Clinic
SPAR
Kilroy's College
Dial a Short Let
Callaghan Engineering
Rostrevor Terrace
Hogan Avenue
Richmond Marketing Limited
Independent Trustee Company
Perrigo Company
Stage Lighting Centre
Dublin2Bike Cycle Shop
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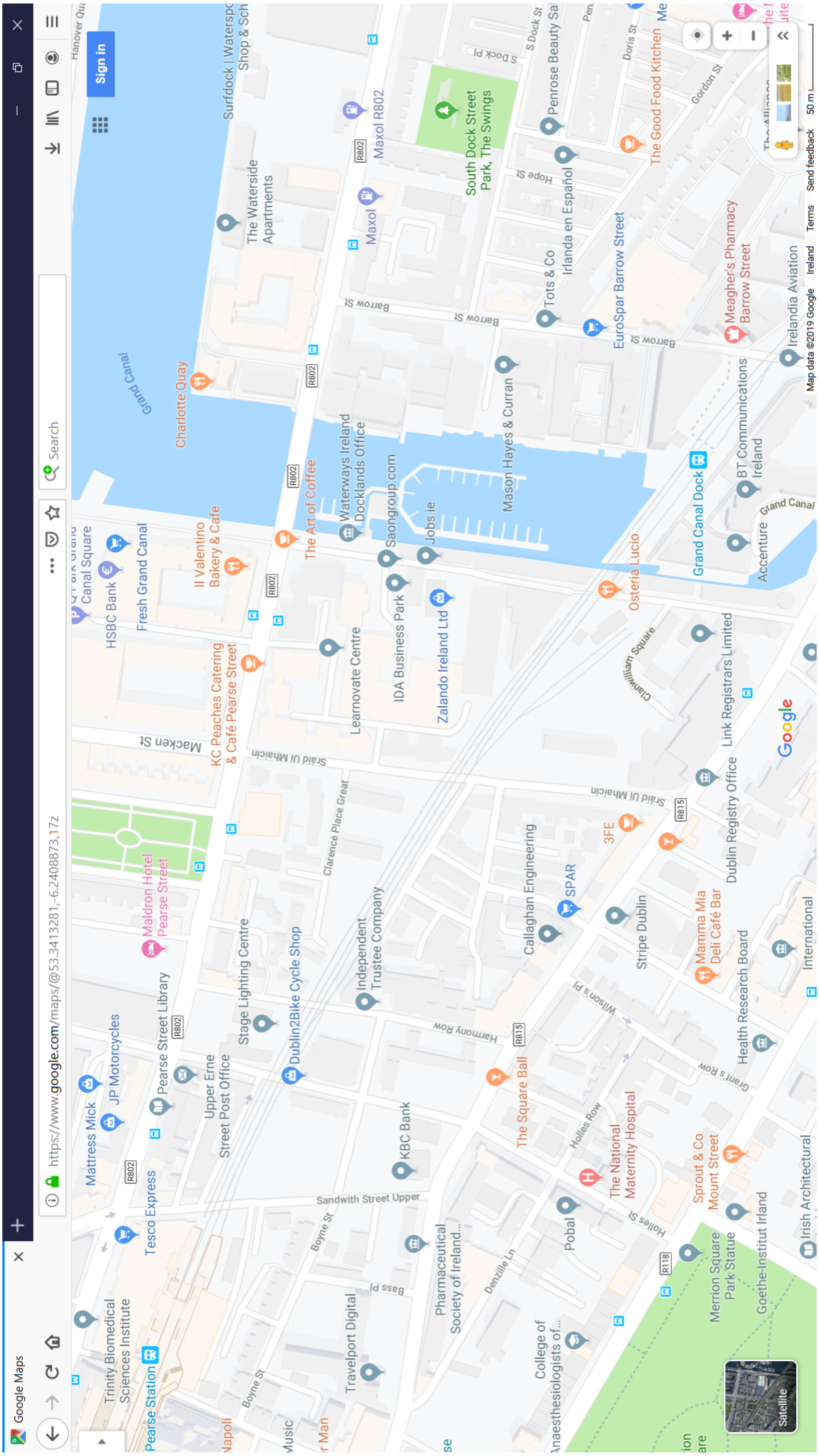
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The Good Food Kitchen
Tots & Co
Irlanda en Español
EuroSpar Barrow Street
Meagher's Pharmacy Barrow Street
Irelandia Aviation
Barrow St
Hope St
Waterways Ireland Docklands Office
Saongroup.com
Jobs.ie
Mason Hayes & Curran
The Art of Coffee
Il Valentino Bakery & Cafe
Fresh Grand Canal
HSBC Bank
Learnovate Centre
IDA Business Park
Zalando Ireland Ltd
Osteria Lucio
Grand Canal Dock
BT Communications Ireland
Accenture
KC Peaches Catering & Café Pearse Street
Macken St
Sráid Uí Mhaicín
Clanwilliam Square
Link Registrars Limited
Dublin Registry Office
Maldron Hotel Pearse Street
Clarence Place Great
Stage Lighting Centre
Dublin2Bike Cycle Shop
Independent Trustee Company
Callaghan Engineering
SPAR
3FE
Stripe Dublin
Mamma Mia Deli Café Bar
Health Research Board
International
Mattress Mick
JP Motorcycles
Pearse Street Library
Upper Erne Street Post Office
Harmony Row
Wilson Pl
Grant's Row
The Square Ball
Holles Row
The National Maternity Hospital
Sprout & Co Mount Street
KBC Bank
Sandwith Street Upper
Tesco Express
Pearse Station
Trinity Biomedical Sciences Institute
Travelport Digital
Pharmaceutical Society of Ireland...
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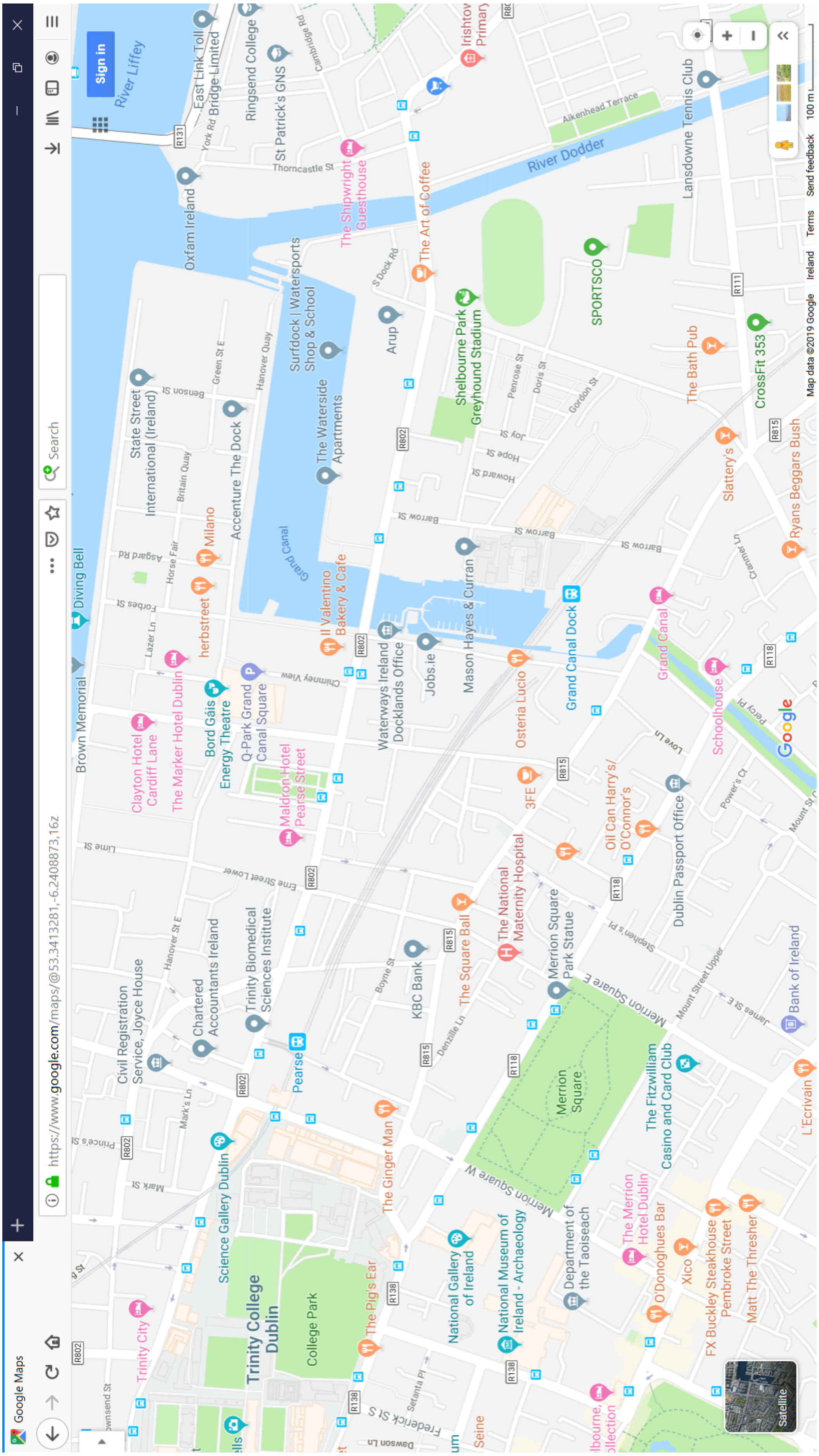

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East Link Toll Bridge Limited
Ringsend College
St Patrick's GNS
Oxfam Ireland
Diving Bell
Brown Memorial
State Street International (Ireland)
Accenture The Dock
Milano
herbstreet
The Marker Hotel Dublin
Clayton Hotel Cardiff Lane
Bord Gáis Energy Theatre
Q-Park Grand Canal Square
Maldron Hotel Pearse Street
Surfdock | Watersports Shop & School
The Waterside Apartments
Grand Canal
Il Valentino Bakery & Cafe
Waterways Ireland Docklands Office
Jobs.ie
Mason Hayes & Curran
The Shipwright Guesthouse
The Art of Coffee
Arup
Shelbourne Park Greyhound Stadium
River Dodder
SPORTSCO
Lansdowne Tennis Club
The Bath Pub
CrossFit 353
Slattery's
Ryans Beggars Bush
Osteria Lucio
Grand Canal Dock
Schoolhouse
3FE
Oil Can Harry's/ O'Connor's
Dublin Passport Office
Civil Registration Service, Joyce House
Chartered Accountants Ireland
Trinity Biomedical Sciences Institute
Pearse
KBC Bank
The Square Ball
The National Maternity Hospital
Merrion Square Park Statue
Merrion Square
Bank of Ireland
Science Gallery Dublin
The Ginger Man
Trinity College Dublin
College Park
The Pig's Ear
National Gallery of Ireland
National Museum of Ireland - Archaeology
Department of the Taoiseach
The Merrion Hotel Dublin
The Fitzwilliam Casino and Card Club
L'Ecrivain
O'Donoghues Bar
Xico
FX Buckley Steakhouse Pembroke Street
Matt The Thresher
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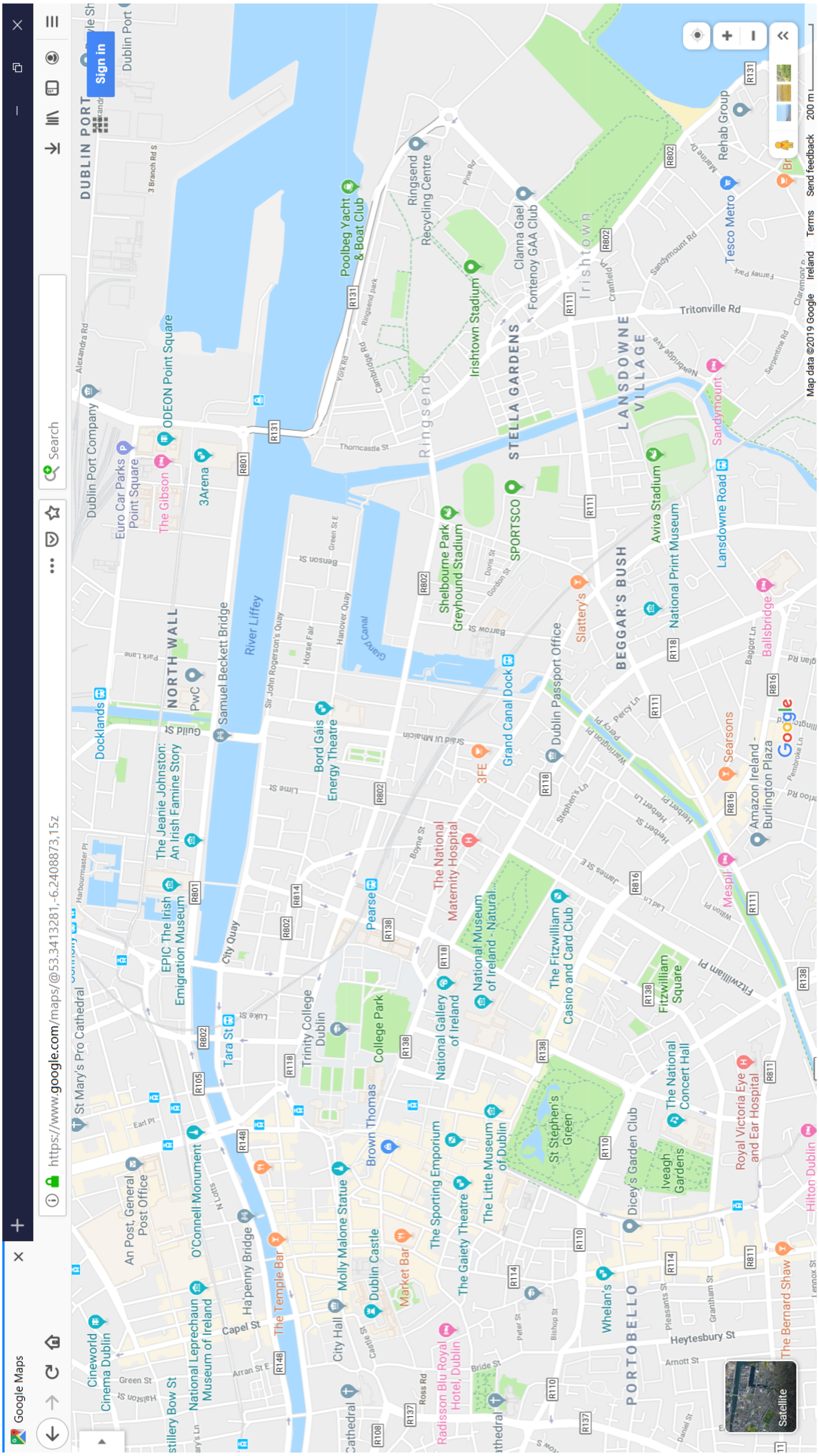
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3Arena
NORTH WALL
PwC
Samuel Beckett Bridge
River Liffey
Docklands
The Jeanie Johnston: An Irish Famine Story
EPIC The Irish Emigration Museum
Bord Gáis Energy Theatre
Grand Canal
Grand Canal Dock
Poolbeg Yacht & Boat Club
Ringsend Recycling Centre
Ringsend
Irishtown Stadium
Irishtown
Clanna Gael Fontenoy GAA Club
STELLA GARDENS
SPORTSCO
Shelbourne Park Greyhound Stadium
LANSDOWNE VILLAGE
Aviva Stadium
Lansdowne Road
National Print Museum
BEGGARS BUSH
Slattery's
Dublin Passport Office
3FE
Searsons
Amazon Ireland - Burlington Plaza
Ballsbridge
Sandymount
Tesco Metro
Rehab Group
Tritonville Rd
Mespil
Fitzwilliam Square
The Fitzwilliam Casino and Card Club
The National Maternity Hospital
National Museum of Ireland - Natural...
National Gallery of Ireland
Pearse
Trinity College Dublin
College Park
Tara St
City Quay
Brown Thomas
St Stephen's Green
The National Concert Hall
Iveagh Gardens
Royal Victoria Eye and Ear Hospital
Hilton Dublin
The Bernard Shaw
Dicey's Garden Club
Whelan's
PORTOBELLO
Heytesbury St
The Little Museum of Dublin
The Gaiety Theatre
The Sporting Emporium
Market Bar
Dublin Castle
Molly Malone Statue
City Hall
The Temple Bar
Ha'penny Bridge
O'Connell Monument
An Post, General Post Office
St Mary's Pro Cathedral
National Leprechaun Museum of Ireland
Cineworld Cinema Dublin
Radisson Blu Royal Hotel, Dublin
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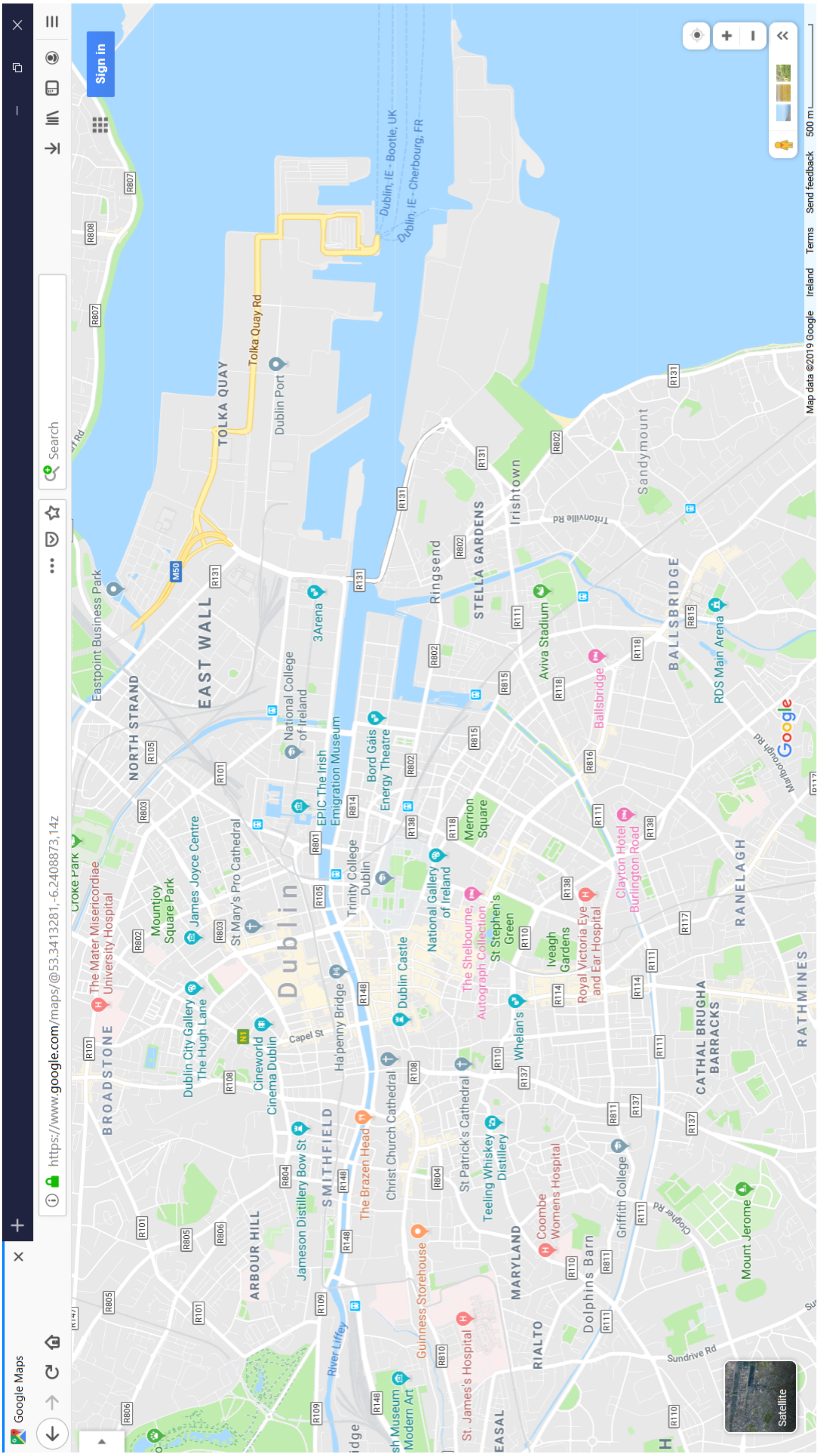

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Eastpoint Business Park
3Arena
National College of Ireland
EPIC The Irish Emigration Museum
Bord Gáis Energy Theatre
Ringsend
Irishtown
STELLA GARDENS
Aviva Stadium
Sandymount
BALLSBRIDGE
RDS Main Arena
Ballsbridge
Trinity College Dublin
Merrion Square
National Gallery of Ireland
The Shelbourne, Autograph Collection
St Stephen's Green
Iveagh Gardens
Royal Victoria Eye and Ear Hospital
Clayton Hotel Burlington Road
RANELAGH
RATHMINES
CATHAL BRUGHA BARRACKS
Mount Jerome
Griffith College
Dolphins Barn
Coombe Womens Hospital
MARYLAND
RIALTO
Teeling Whiskey Distillery
St Patrick's Cathedral
Whelan's
Dublin Castle
Ha'penny Bridge
Christ Church Cathedral
The Brazen Head
Guinness Storehouse
St. James's Hospital
River Liffey
SMITHFIELD
Jameson Distillery Bow St
ARBOUR HILL
Cineworld Cinema Dublin
Dublin City Gallery The Hugh Lane
James Joyce Centre
St Mary's Pro Cathedral
Mountjoy Square Park
The Mater Misericordiae University Hospital
BROADSTONE
Croke Park
Capel St
Trimleston Rd
Sundrive Rd
Clogher Rd
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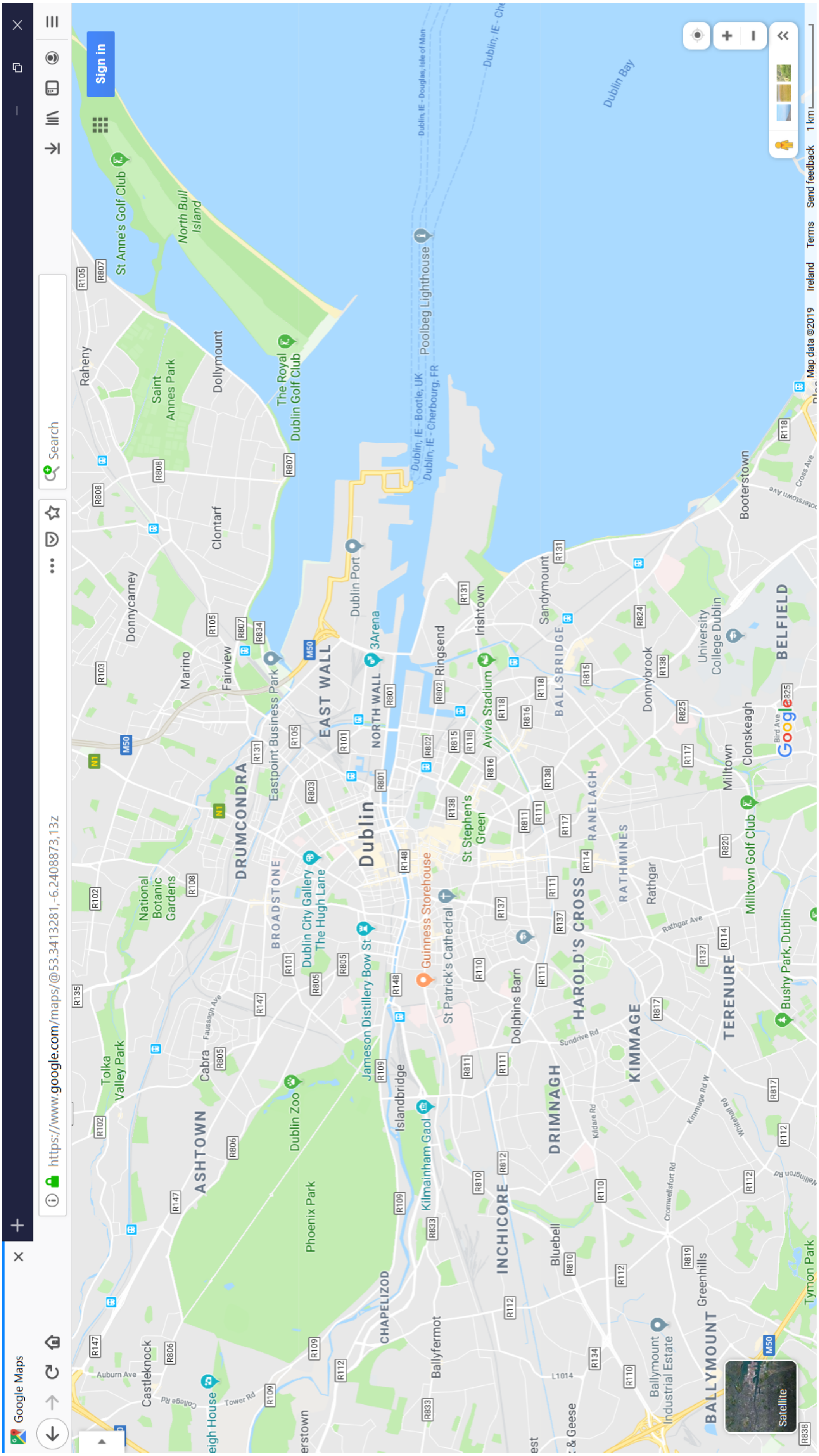
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Dollymount
Donnycarney
Marino
Fairview
Drumcondra
East Wall
North Wall
3Arena
Ringsend
Irishtown
Sandymount
Aviva Stadium
Ballsbridge
Donnybrook
University College Dublin
Booterstown
Belfield
Clonskeagh
Milltown
Ranelagh
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Harold's Cross
Kimmage
Terenure
Drimnagh
Crumlin
Inchicore
Bluebell
Dolphins Barn
St Patrick's Cathedral
Guinness Storehouse
St Stephen's Green
Jameson Distillery Bow St
Dublin City Gallery The Hugh Lane
Broadstone
Eastpoint Business Park
Islandbridge
Kilmainham Gaol
Chapelizod
Phoenix Park
Dublin Zoo
Ashtown
Cabra
Tolka Valley Park
National Botanic Gardens
Castleknock
Ballyfermot
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Ballymount
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Map data ©2019 Ireland Terms Send feedback 1 km
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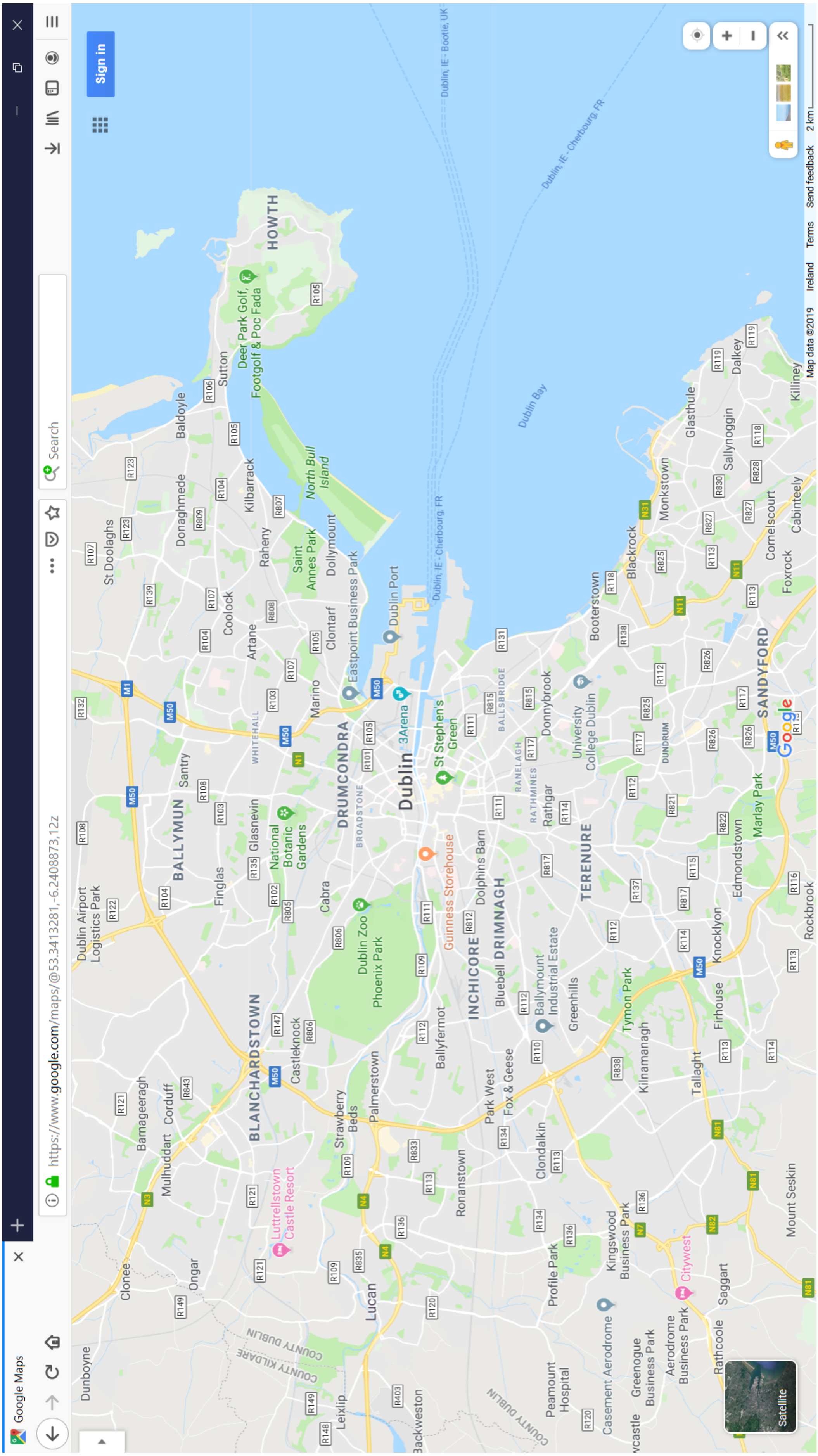
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INCHICORE
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TERENURE
SANDYFORD
Phoenix Park
Dublin Zoo
Guinness Storehouse
St Stephen's Green
3Arena
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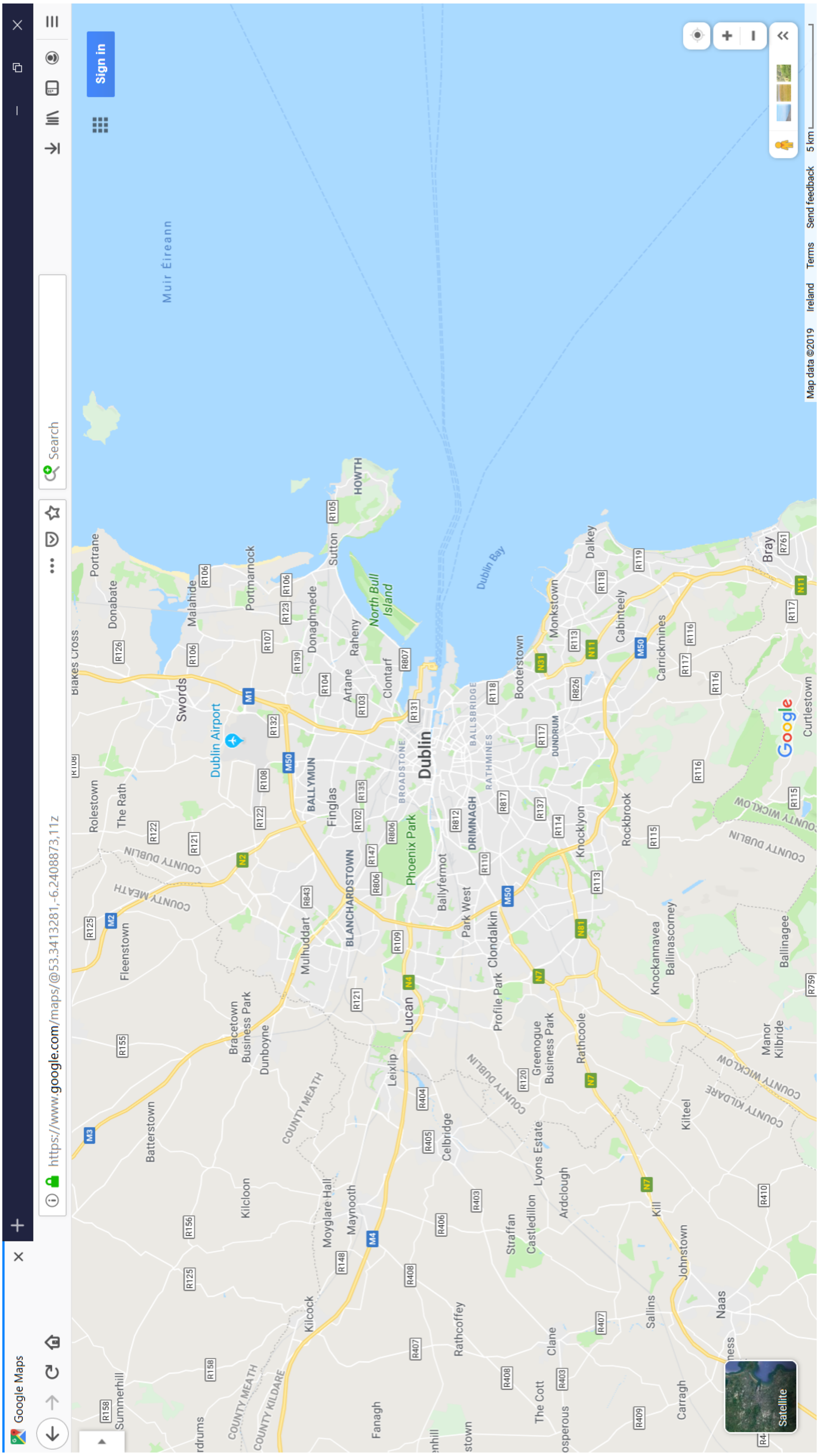
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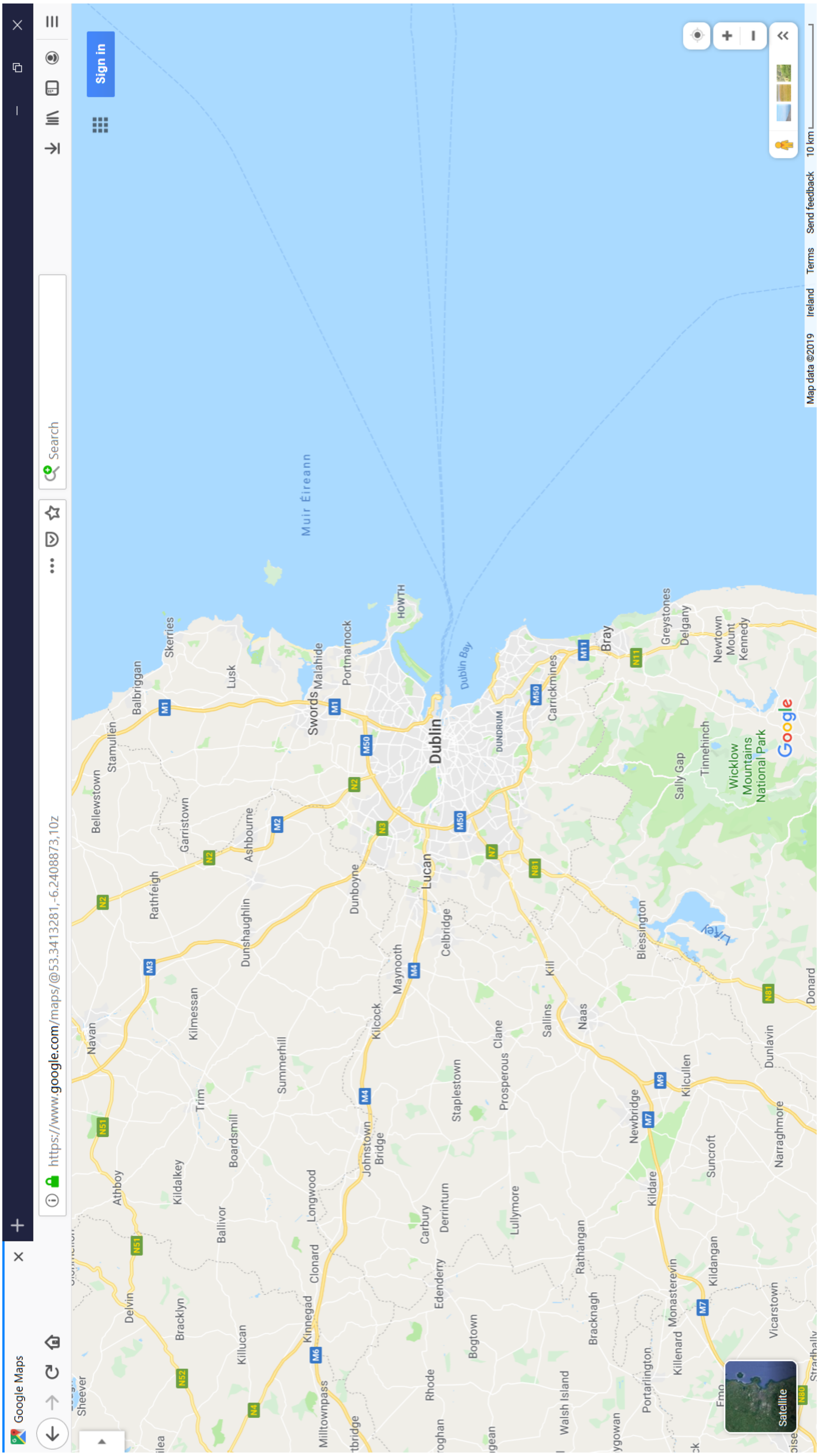
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Rathfeigh
Dunshaughlin
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Lucan
Celbridge
Maynooth
Kilcock
Navan
Kilmessan
Trim
Summerhill
Johnstown Bridge
Longwood
Kildalkey
Athboy
Ballivor
Boardsmill
Killucan
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Kinnegad
Clonard
Carbury
Derrinturn
Edenderry
Rhode
Bogtown
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Prosperous
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Kilcullen
Kildare
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Bracknagh
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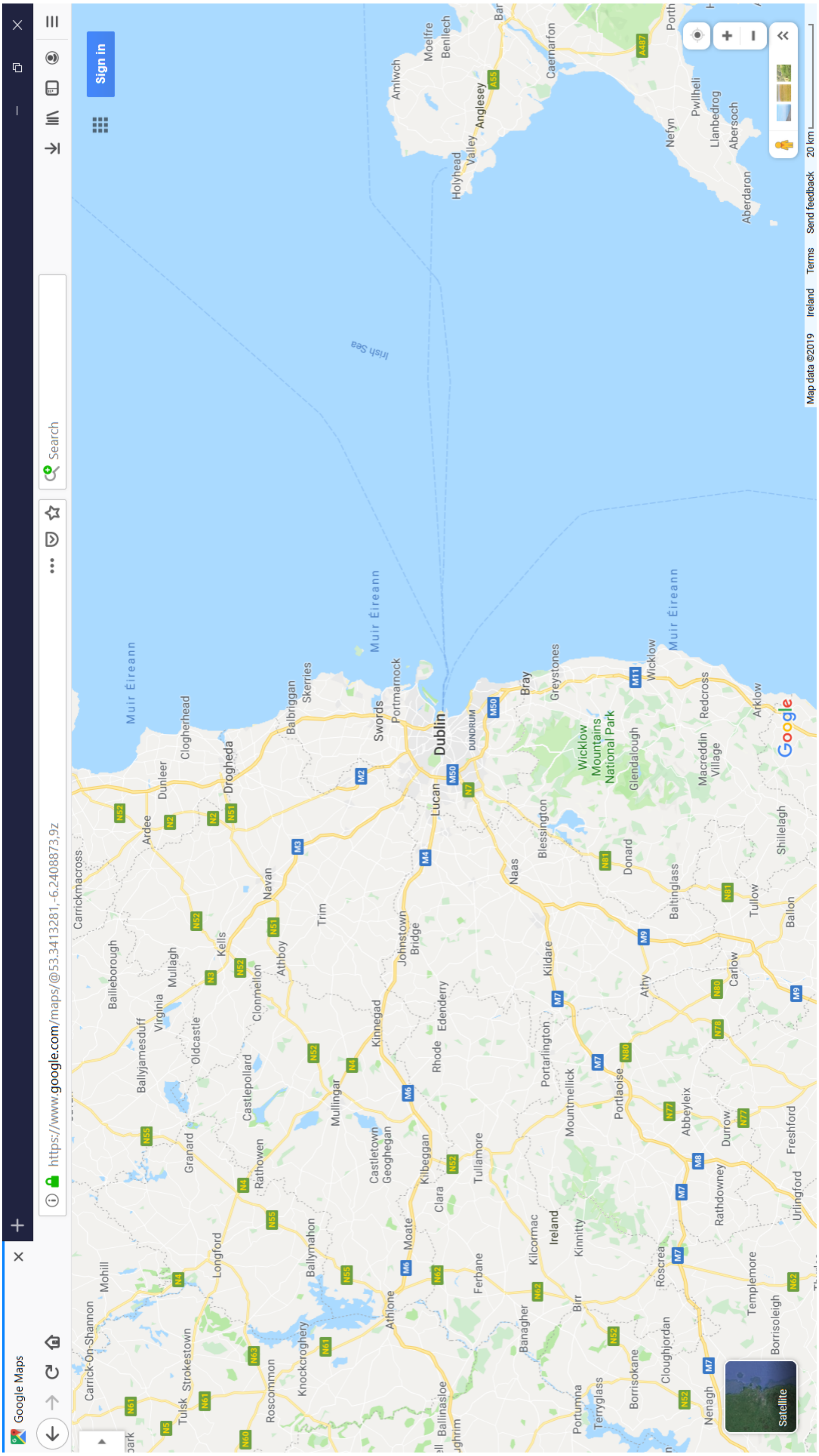
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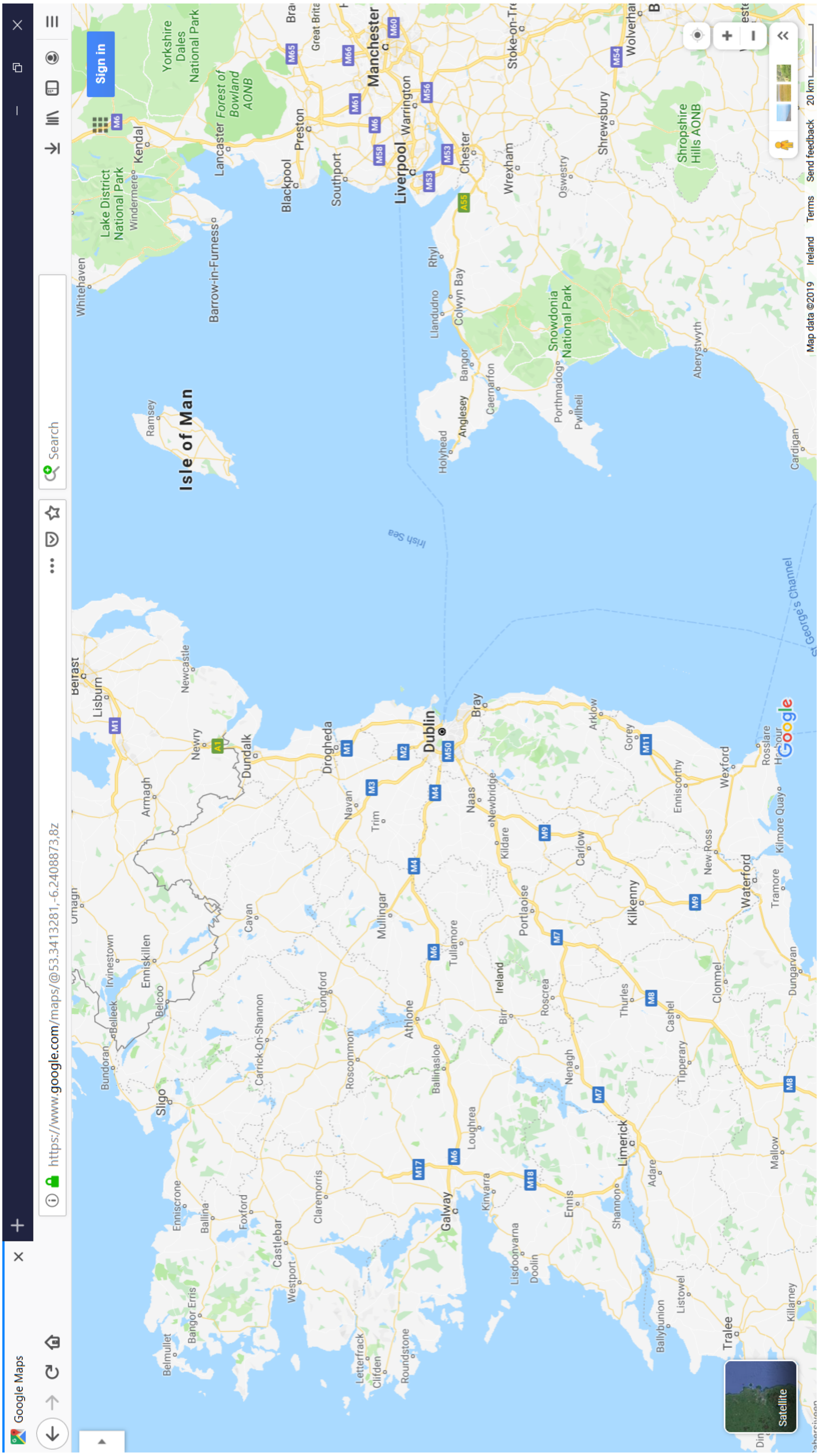

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Kilkenny
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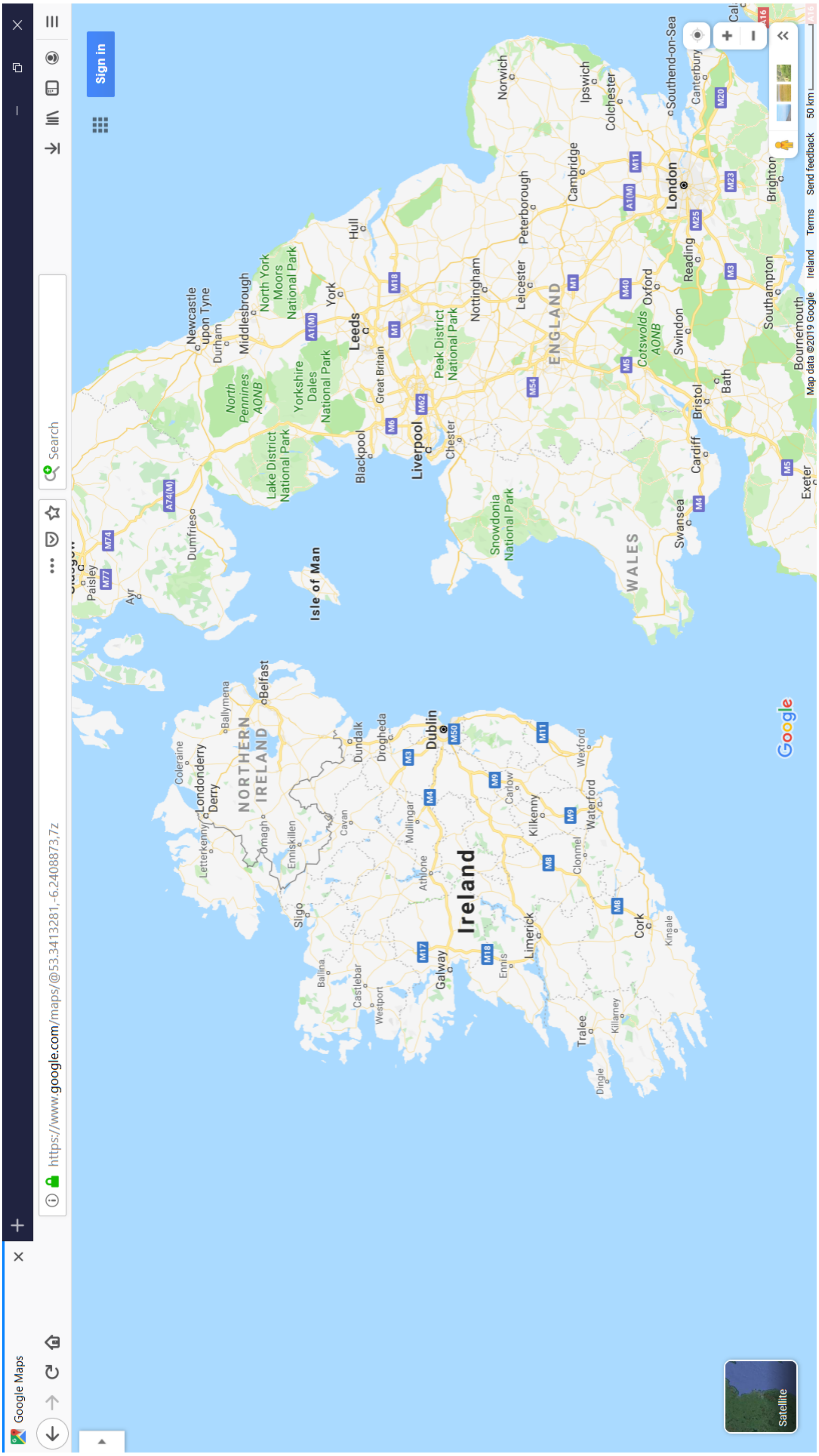
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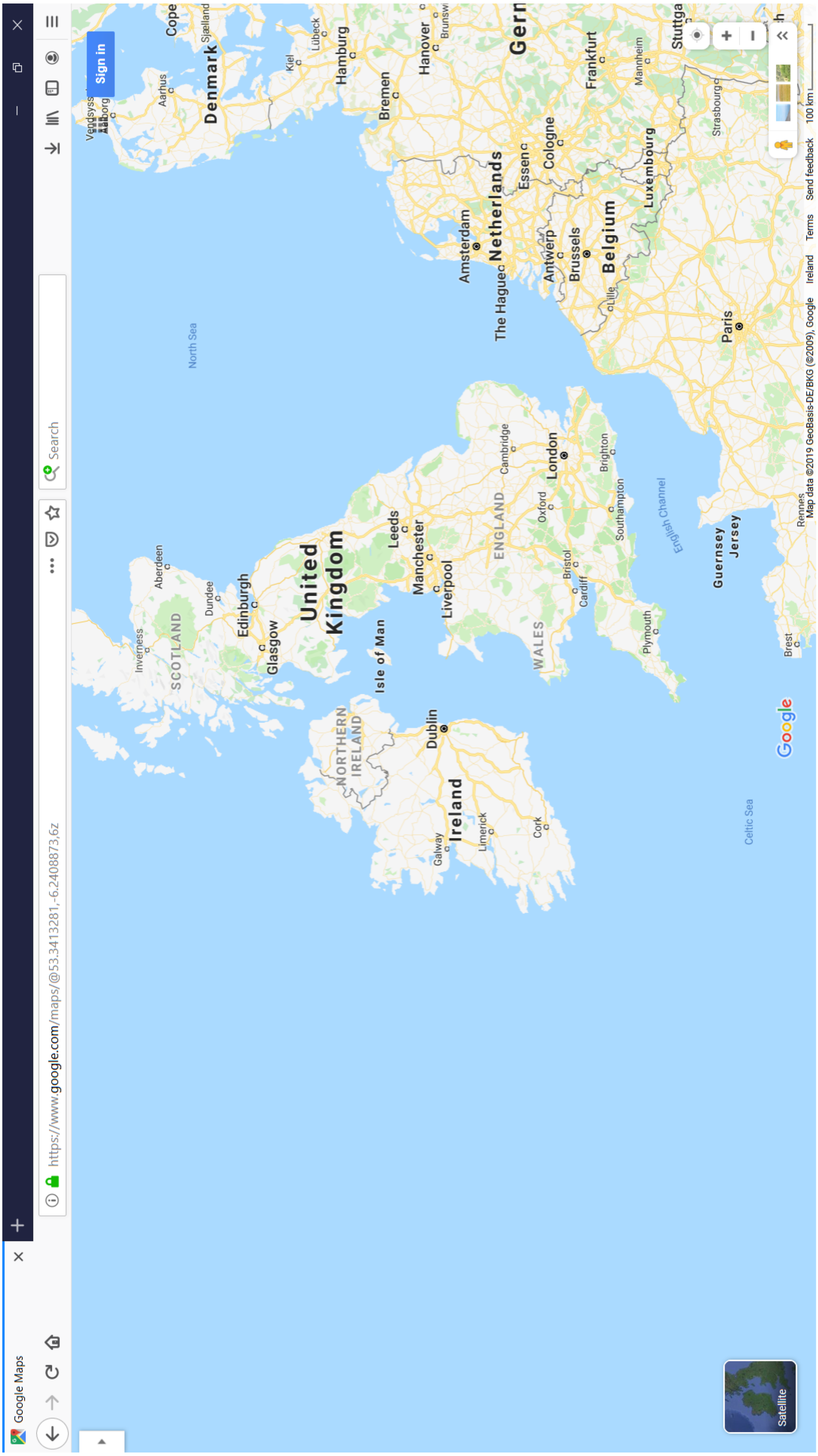
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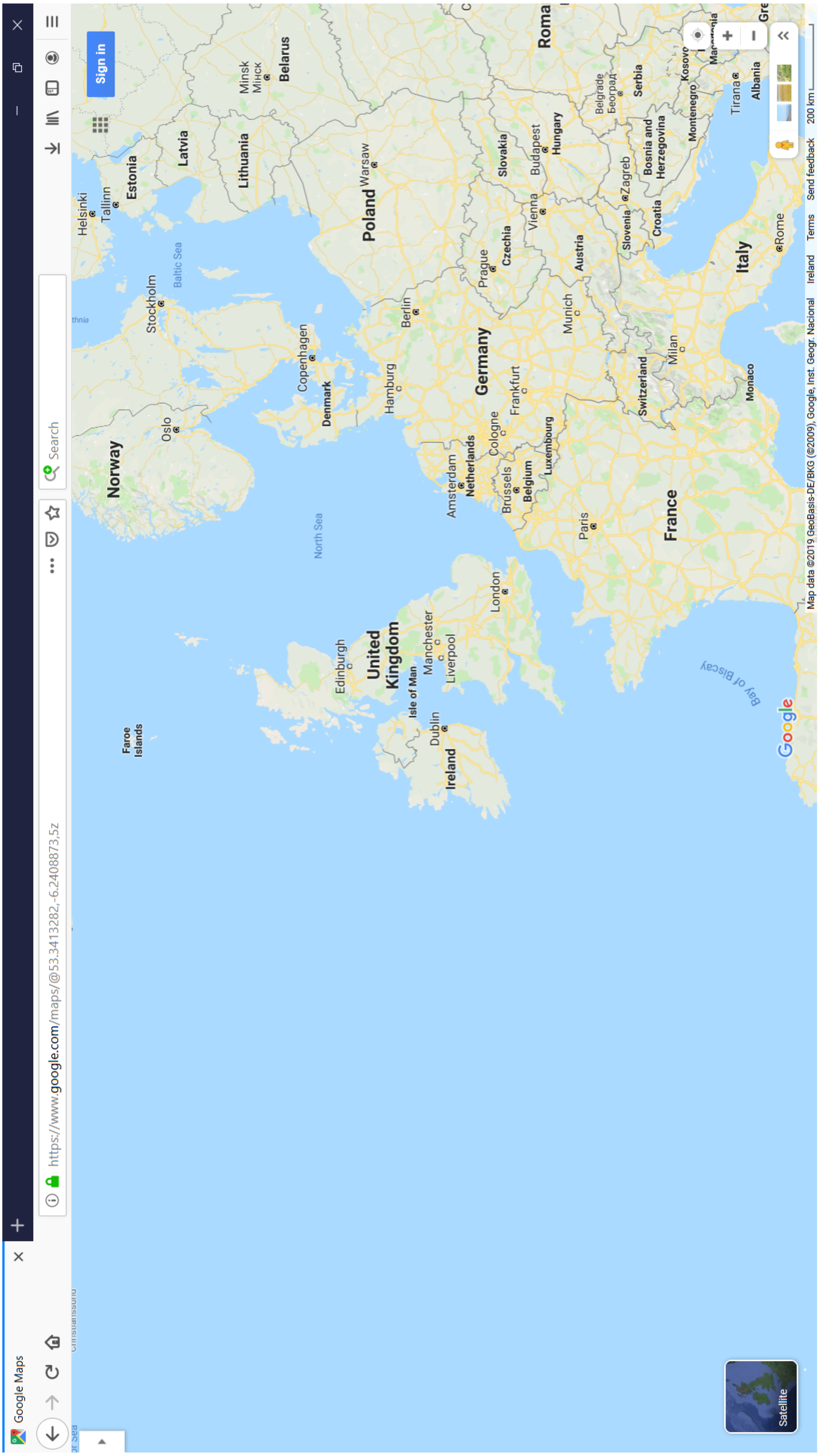

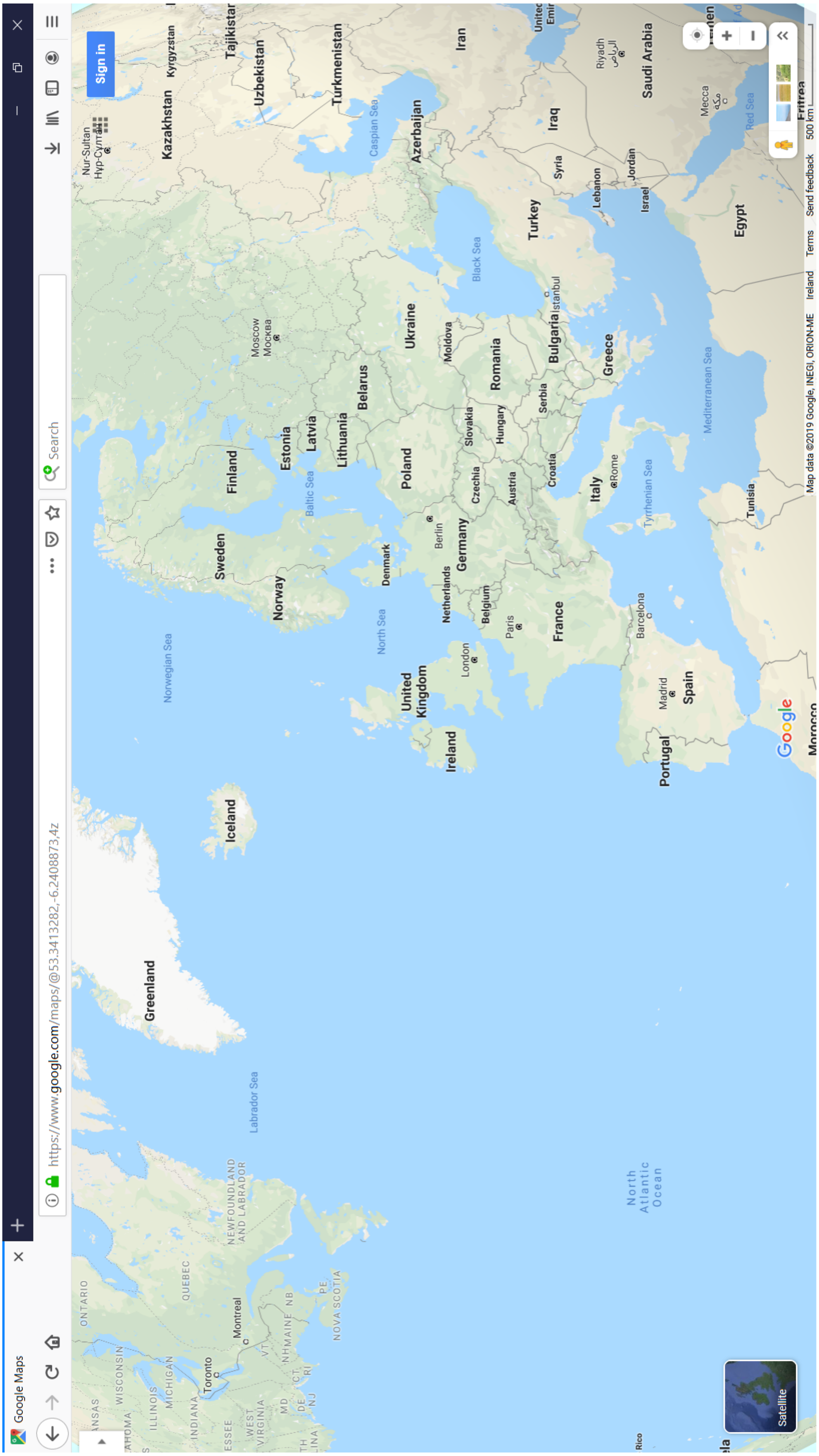
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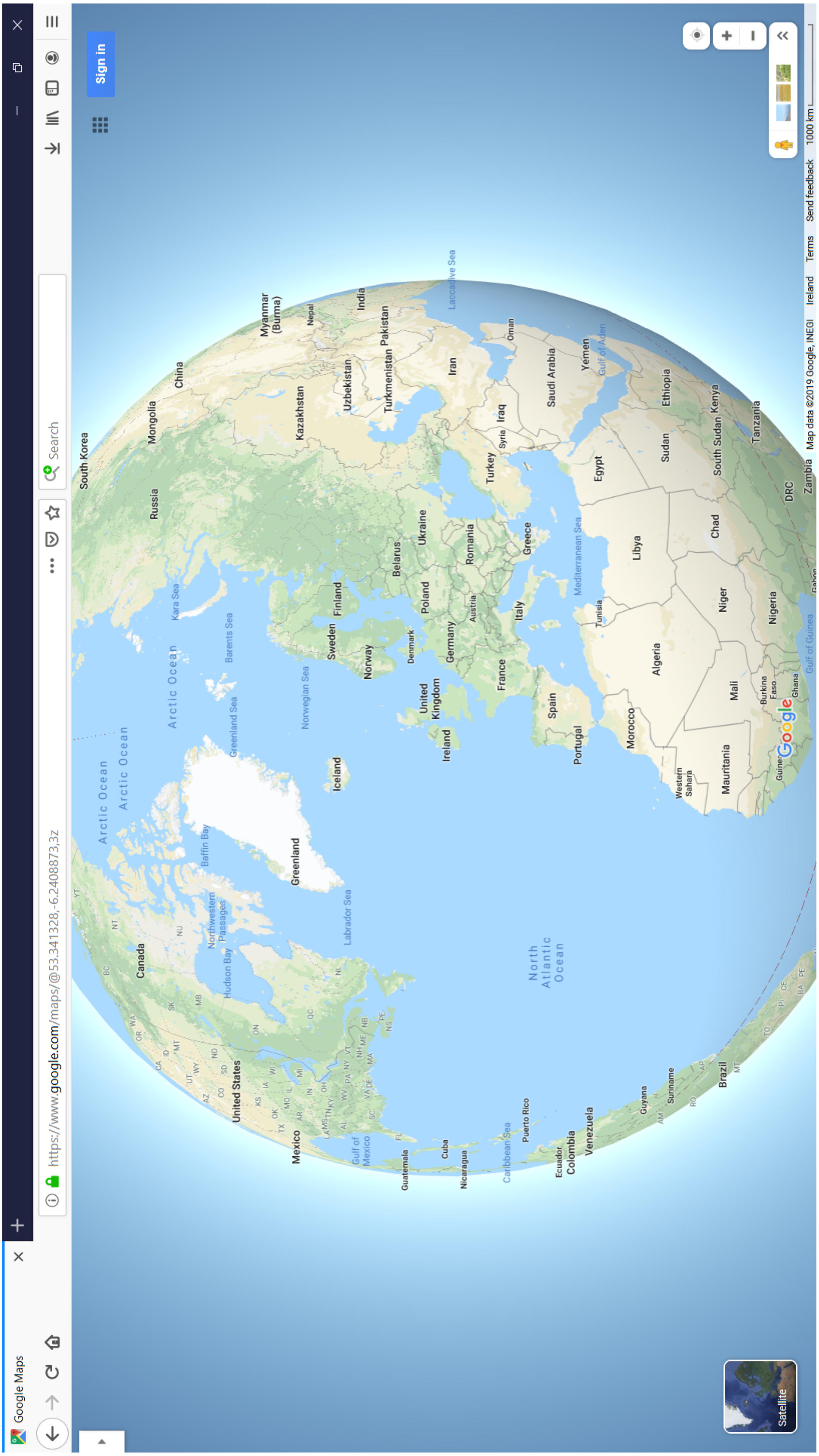
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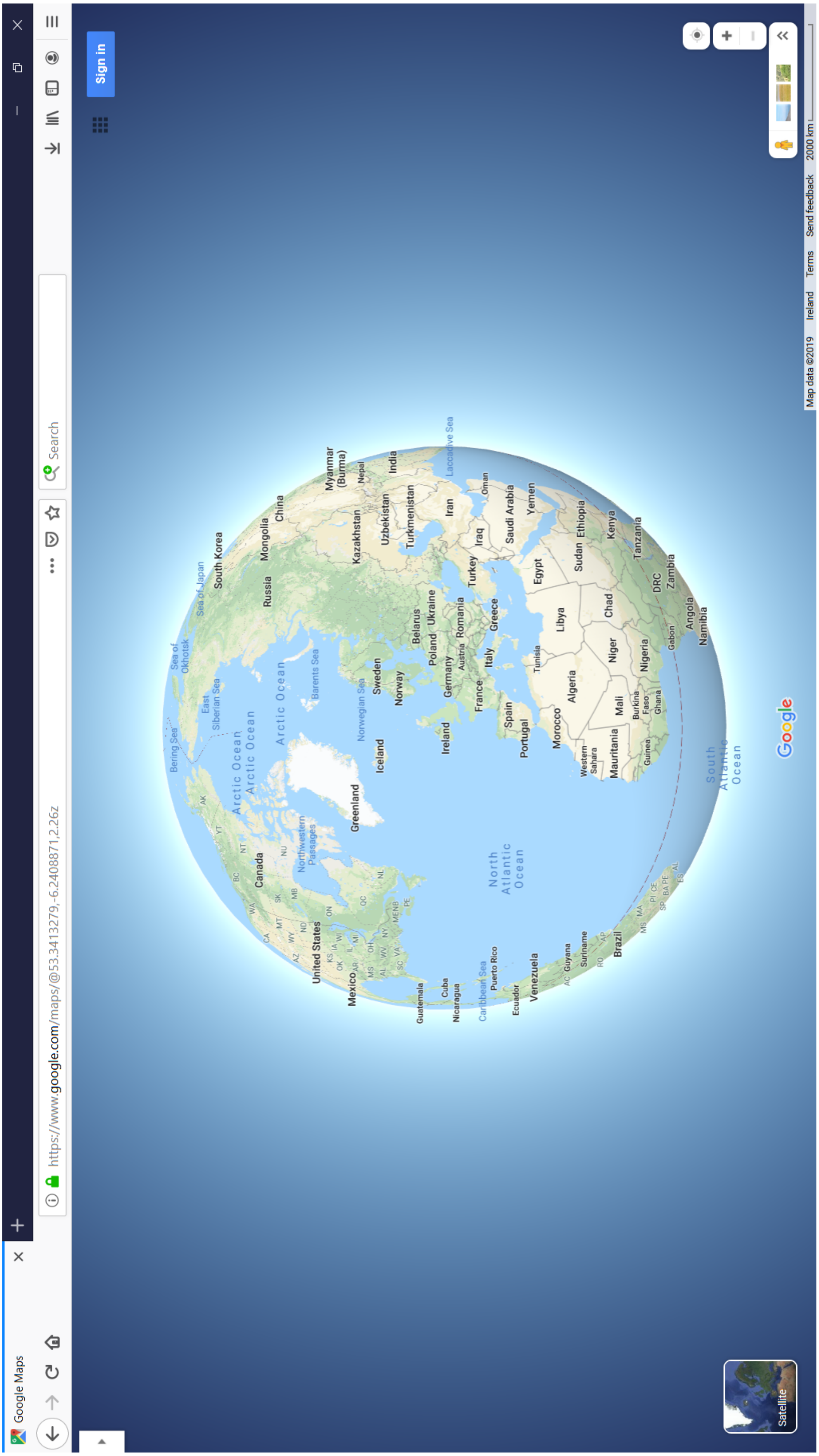
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