http://revistes.ub.edu/index.php/matter
Vol 3 No 1 (February 2022)
ISSN: 2604-7551

VOL 3 NO 1

Prospects for a New Materialist Informatics

UNIVERSITAT DE BARCELONA

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MATTER Journal of New Materialist Research

Universitat de Barcelona
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Prospects for a New Materialist Informatics: Introduction to a Special Issue

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DOI: https://doi.org/10.1344/jnmr.v3i1.38955

In her interview with Lisa Nakamura in 2003, Donna Haraway called for "prospects for a materialist informatics" that is attentive to the kinds of humanness and machineness that are produced in material-semiotic encounters with/in technology, and to the kinds of perspectives that do not fit well the technoscientific norms of such encounters (Nakamura & Haraway, 2003). Building on the work of Donna Haraway, Katherine Hayles (1999), Nakamura (Kolko et al., 2000; Nakamura, 2008), and a plethora of cyberfeminist scholars and activists (Fernandez et al., 2003; Sollfrank, 2018), the racialized, classed, sexed and otherwise variously "normed" (both in a positive and negative sense) materializations of and in informatics have been an important area of research both in new materialist scholarship (Colman, 2015; Colman et al., 2018; Ernst et al., 2017; Lorenz-Meyer et al., 2019; Papenburg et al., 2018), as well as in science and technology studies (STS) and technology critique in general. We can think here, for instance, of the many recent works that investigate the relation between structural inequalities and AI/machine learning technologies (e.g., Benjamin, 2019; Eubanks, 2018; Noble, 2018; O'Neil, 2017). It is noteworthy that most of these discussions were brought to the fore by women of color and Black women.

New materialist perspectives are also slowly taking root in informatics as a discipline. For instance, the 2020 ACM's Designing Interactive Systems conference[1] had an

[1] ACM stands for "Association for Computing Machinery" and is one of the largest international professional associations of computer scientists. For more about the specific conference, see https://dis.acm.org/2020/ (accessed on 17.02.2022).

explicit new materialist focus, as did several contributions in the conferences on human-computer interaction (HCI), participatory design (PD), computer-supported cooperative work (CSCW), human-robot interaction (HRI), and interactive systems design in recent years (Draude, 2020; Fischer et al., 2019; Frauenberger, 2020; Freeman et al., 2019; Homewood et al., 2021; Klumbyte et al., 2020; Pihkala & Karasti, 2018; Ståhl et al., 2021; Treusch et al., 2020). Some argue that there is a new "entanglement HCI" perspective emerging that takes up not least concepts from new materialism to introduce a new perspective in HCI and interaction design more generally that is attentive to material-semiotic entanglements and approaches worldmaking with technology as always already more-than-human (Frauenberger, 2020; Homewood et al., 2021; Niemimaa, 2016). This highlights that informatics inherently *is* a material-semiotic discipline, which is constituted by sign/signal processing and tied to hardware, tech infrastructures and embeddedness in material worlds (Nadin, 2007).

This research, spanning humanities, social sciences, arts, and computer science and design, is the context in which the conference on New Materialist Informatics took place in Kassel, Germany, on 22-25 March 2021. Being an 11th international new materialisms conference, it aimed to root and further the research in and of informatics that starts from and enacts new materialist approaches in AI/ML (machine learning), software engineering, robotics, critical algorithm studies and critical digital studies, STS, design, artistic research, HCI, and media studies, among others. The overall hope was to create space to consolidate research that could fit under the umbrella of new materialist informatics (NMI) thus also performatively instituting the field. However, all the aforementioned references notwithstanding, it turned out to be a challenging, and perhaps impossible, task to demarcate NMI as a field in a concise way. This is not least because NMI, as an investigation of (new) material(ist) concerns in, approaches to and enactments of informatics – itself understood as both a research discipline and a field of practice – relies on approaches to materiality that can be traced back to different traditions of scholarship and praxis.

We attribute this most importantly to the fact that materiality figures differently within humanities and social sciences (SSH), and more technical and practice-oriented fields such as informatics. In the former, materiality, as it meets media and technology, is

addressed through materialist media theories, both new (Parikka, 2011, 2015) and more classical theories often originating in the German context (Bollmer, 2019; Kittler, 1992), Marxist and political economy-oriented research (e.g., Gottlieb, 2018; Pötzsch, 2017), while the vitality of matter as well as material-discursive entanglements are taken up more in aforementioned new materialist scholarship. Informatics, on the other hand, includes both imaginaries of disembodiment – as evidenced in, for instance, reliance of metaphors such as clouds, *soft*ware, as well as the general imaginary of abstraction and abstract thought as disembodied (e.g., Haraway, 1997). However, informatics also needs to work with a clear understanding of the material basis of information technologies and thus also the material capacities and constraints – from reliance on minerals and other natural resources to make technology do its work, to material practices of design, to material configurations of hardware and software (Blanchette, 2011; Chien, 2019; Dourish, 2017; Hayles, 1992; Jung & Stolterman, 2012). These differences also show in the different understandings and interpretations of "matter" and “material” in "new materialism" as it meets informatics.

Such plethora of approaches to materiality within and of informatics, we believe, is not necessarily a problem but rather a possibility for the field of NMI to remain open to multiple genealogies. Furthermore, when it comes to specifically *new* materialism and informatics, there are fruitful cross-pollinations to be made. First, the way materiality is addressed in informatics could benefit from new materialist understanding of matter as agentive and relational, and technologies as material-discursive configurations, to use Lucy Suchman’s term (Suchman, 2006), that enact specific worldings of humanness and machineness. Secondly, new materialist scholarship could benefit from informatics’ attentiveness to what matter (as and in technology) can do, how matter itself is rendered informational, and, methodologically, the pragmatic and design-oriented methodologies.

This polyvocality, in terms of genealogies of materialisms, disciplines of research, and praxes of engagement, is what we aimed at maintaining both throughout the conference in 2021, as well as in this special issue. Apart from the different takes on matter and mattering, the articles in this special issue present different disciplinary crossovers and convergences between arts, HCI, engineering, media and culture

studies, philosophy, political economy, robotics, architecture, and design. Accordingly, they also present different methods, varying from historical genealogies, computational experiments, to theoretical analyses and theory-led interventions. This methodological diversity is, we argue, crucial for NMI as an emerging transdisciplinary field.

The articles by Ziyuan Meng & Jon Burmeister on "Cybersecurity and Simondon's Concretization Theory: Making Software More Like a Living Organism" and by Petra Gemeinboeck on "Difference-In-Relation: Diffracting Human-Robot Encounters" present the crossovers between software engineering and philosophy, and performance and human-robot interaction, respectively. Addressing these rather established disciplines, these contributions perform a diffractive re-reading of computational practices – human-robot interaction design and cybersecurity software engineering – with new materialist philosophies and concepts, which also has implications for how said practices can be performed.

Meng and Burmeister rely on Simondon's theory of concretization and individuation to draw parallels between the development and interaction of living organism with its environment, and software. The article introduces Simondon's terms of concretization, individuation, and associated milieu, among others, and argues that software and its behaviour, particularly in cybersecurity context, can and should be approached more as a living organism, blurring the boundaries between material/immaterial, living/non-living, natural/technical. This further highlights the processual, living, dynamic materiality of software and technology in general, and shows how Simondon's non-anthropocentric view of technicity can have implications for software engineering approaches.

Gemeinboeck's contribution bears implication for the understanding and design of human-robot interaction (HRI). She investigates how HRI can be re-imagined not as predicated on achieving sameness or similarity (robots mimicking humans and their ways of inter/action), but rather on establishing interaction while maintaining ontological difference. Drawing on new materialist concepts such as intra-action and diffraction (Barad, 2007), Gemeinboeck questions the normative humanness that often is implied in HRI and develops *bodying-thinging* as a concept that helps

understand the ongoing material attunement between human and non-human bodies, inserting relational ontology at the core of HRI and human-robot experience design.

Relationality and onto-epistemological questions are an important theme also in Selena Savić's contribution "Articulating Nomadic Identities of Radio Signals" and Lisa Müller-Trede's "Discerning Relational Data in Breath Patterns: Gilbert Simondon's Philosophy in the Context of Sequence Transduction." Savić investigates the onto-epistemology of radio signals and ways of knowing them with data observatories and machine learning (ML) algorithms. Proposing that radio signals both are matter and do matter(ing), she argues that their nomadic identity can be articulated with ML processes without essentializing or de-contextualizing them – something that is often done when categorizations are performed with contemporary ML technologies. Bringing together new materialist thought, media theory and experimental research, Savić demonstrates how to think with and work with computation in material, engaged and experimental way.

Müller-Trede also employs computational experimentation to think with and through relationality. Working with breath patterns, ML sequence transduction model, and Simondon's theory of transduction and intensity (2017), she presents an example of computation that deals with relational information and intensities, while retaining the singularity, collectivity, and contextualization of such intense data. Müller-Trede thus shows not only that technical objects are relational, but also that computing, and specifically ML technologies, can address and amplify singularity and relationality without immediate and fixed categorization. This points to the importance of investigating what else computing can do beyond its more conventional uses.

One of such different uses is speculative exploration, which is presented in Yota Passia's and Panagiotis Roupas' work "Manifold Spaces and Patterned Potentialities." Bringing together architectural theory, continental philosophy of Deleuze & Guattari, and experimental design, Passia and Roupas investigate how space can be imagined and configured differently through a manifold. Inventing a speculative "anticipation apparatus," they think through information as a form of matter that is spatially distributed and interactive, allowing to explore intensity, transformation and change in urban environments. This contribution enacts ways of working with abstraction,

materiality, creativity, and potentiality in a generative way, which are important concepts in addressing limits and possibilities of information technologies.

Material settings of contemporary information technologies are also explored in Harald Kümmerle's article "Japanese Data Strategies, Global Surveillance Capitalism, and the 'LINE Problem,'" albeit in a very different sense. Kümmerle brings together political economy and historical analysis and draws a geopolitical cartography of data discourses and politics from the perspective of Japan. He presents a tracing of infrastructure, political actors, experts, nationalist/international/colonial-imperial discourses, and strategies – and weaves this into a detailed narrative that contributes to a better understanding of global data regimes and their interconnections with surveillance capitalism. Less exemplary of the "new" and more of "materialist" scholarship, this is an informative interlude in the more theoretical/conceptual and design perspectives offered by other articles in this issue. It is also significant particularly because power dynamics around data are all too often primarily from US-American or European perspectives.

The two intra-views in this special issue also contribute to thinking about the geo-, techno-, racial and controlling politics of computing and its practices. The intra-view on "Contagious Education" by P. Taylor Webb, Marcelina Piotrowski and Petra Mikulan, explores how contemporary information technologies can loosen the grip of normative education and instead allow for "digital contagion" towards different practices of learning. Speaking to the context of education research, the authors discuss how these technologies can disrupt the way that education is currently governed towards biopolitical, racialized and extractive datafication. Exploring the concepts of contagion, overspill, and life as excess, Webb, Piotrowski and Mikulan suggest that technologies can be used to jam the mechanisms of computational and other forms of control.

"Speculative Materialities, Indigenous Worldings and Decolonial Futures in Computing & Design" invited Indigenous researcher and game designer Outi Laiti, artists and researchers Femke Snelting, Luiza Prado de O. Martins and Caroline Ward to share their practices and explore some of the pressing political questions in computing and computational imagination. What infrastructures and communal spaces do we need for *otherwise* practices in computing? What political strategies help reimagine

computing from less dominant perspectives? This is an intra-view that is also a call to continue to push the limits of computing and question the kinds of subjects that are expected to take part in informatics work.

Finally, the two Almanac entries – “Algorithmic Kinning” by Goda Klumbytė and “Stoniness” by Paul Heinicker and Jonas Parnow – conclude this special issue with terms that exemplify the intermingling and co-constitution of matter and information. The former describes how computational condition affects kin-making practices and kinship as a concept, while the latter addresses the materiality of the digital and the informational, or, in other words, the “stoniness” of post-digital materiality[2].

To conclude, we want to point out the political stakes of and possible future directions for new materialist informatics research. In the context of new technologies being implicated in both the Fourth Industrial Revolution and the Sixth Extinction, and the long-standing discourses around dis/embodiment in and of information technologies, it is crucial to pay attention to how matter is accounted for or excluded from accounts of computing infrastructures, conditions, and effects. As we mentioned earlier, the material basis of computing is one dimension of this account. Others are the racialized, sexualized, naturalized and other discriminatory dynamics that unfold in the materializations of informatics. Materialities of bodies in general – human and non-human – thus must be inserted back into accounts and practices of computing, without making assumptions that we know what bodies can do or neatly slotting them into the moulds of categories, to actively work against the deeply entrenched power hierarchies. This is particularly salient in the context of information technologies that order, categorize, govern, and classify life at an unprecedented scale, all the while obscuring their workings and infrastructural premises with metaphors of "black boxes", "clouds", etc. At the same time data and information are also portrayed as the "new oil", thus pointing again to recurring colonialism and extraction (Couldry & Mejias, 2019; Ricaurte, 2019; Thatcher et al., 2016)[3].

As all articles in this issue demonstrate, informatics is staunchly material in its infrastructure and in its effects, even if that materiality is expressed in different ways.

[2] For a collection of resources on post-digital materiality, see Heinicker’s and Parnow’s project https://stones.computer/ (accessed on 18.02.2022).
[3] For more on the entanglements between race, colonialism, and technology, see the materials, including video recordings, of the symposium “Recursive Colonialism”, organised The Critical Computation Bureau, on 1-12 December 2020: https://recursivecolonialism.com/ (accessed on 04.02.2022).

At the same time, it is important for matter to be accounted for in new materialist terms – as a dynamic, agentive, entangled process of mattering. Matter is itself informational and poietic and therefore an active agent in computing. Thus, for the future work in NMI, we argue that it is crucial to generate accounts that demonstrate and further the understanding of material-semiotic, material-informational entanglements and intra-actions that are both actualized and put at stake in computational practices. Furthermore, adequate (re)presentation of positions that are not limited to European, US-American, Western perspectives, such as Indigenous knowledge, are also sorely needed in NMI – the lack that is palpable both in this issue, and in the New Materialist Informatics 2021 conference that it emerges out of[4]. We therefore hope that both in terms of research and in terms of praxis, NMI community will work to create fertile ground for more feminist, post- and de-colonial, trans*feminist, Indigenous and further *otherwise practices*. Last but not least, practice is another keyword for future research. If NMI is to retain its polyvocality and political engagement, we believe that it is important to continue to present ways not only how to engage matter speculatively but also how to speculate materially and think-with informational matters. We hope that the articles presented in this issue provide some inspiring examples of these diverse practices of new materialist informatics.

Acknowledgements

We would like to thank all the peer reviewers for their time and expertise. We are also grateful for the journal's editorial board and team for their support in bringing this special issue to fruition.

The New Materialist Informatics conference at the University of Kassel, Germany, was funded by the German Research Foundation (Deutsche Forschungsgemeinschaft - DFG), and financially and organisationally supported by Research Center for Information System Design (ITeG) at the University of Kassel.

[4] This has also been critically addressed with respect to new materialism as a field in general – see, for instance, Hinton et al. (2015); Sundberg (2014); Todd (2016).

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Cybersecurity and Simondon's Concretization Theory: Making Software More Like a Living Organism

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DOI: https://doi.org/10.1344/jnmr.v3i1.38956

Abstract

The cybersecurity crisis has destabilized the field of informatics and called many of its foundational beliefs into question. This paper argues that Gilbert Simondon's theory of the origin and development of technical objects helps us identify faulty theoretical assumptions within computer science and cybersecurity. In particular, Simondon's view is that the process of the 'individuation' of technical objects can have similarities with the development of living beings – a view that stands in stark contrast with hylomorphic and reductionist views of technical objects currently common in computer science. We argue that those common hylomorphic approaches to software development lead to excessive modularity in software applications, which in turn results in less secure systems. To investigate a new ontological basis of software security, we look to Simondon's ontology to reconsider what makes a piece of software vulnerable in the first place, and we focus on two concepts in his general theory of ontogenesis – 'individuation' and 'associated milieu'. By examining a case study of a malware infection attack, we show that the event of a cyberattack unleashes a 'co-concretization' process of software applications and their associated milieu, namely, their operating system. Both the application and the operating system evolve from an abstract form to a more concrete form by re-inventing their own interiors and re-orienting their relationship to each other. We argue that software development will be more secure if it takes inspiration from the development of living

beings and refocuses on the dynamic reciprocal relationship between software applications and their technical and social environment.

Keywords

Individuation; Information; Cybersecurity; Simondon; Associated Milieu; Software.

Introduction

What does cybersecurity have to do with the highly abstract ontological categories of form and matter, universal and individual? The eminently practical domain of computing and cyber defense might appear to be miles away from the heady heights of metaphysics and ontology. Yet any attempt to understand technical beings and technical processes in a foundational way will go astray if it is founded upon a faulty theory of being. We wish to argue that the current dominant mode of thinking about computers and cybersecurity is in fact based on such a faulty theory of being, and we look to Gilbert Simondon's ontological categories for a stronger account. Simondon's critique of hylomorphism (viewing objects as a combination of form and matter; Simondon, 2009a, p. 4), along with his quasi-biological conceptualization of technical evolution, shed light on the mode of existence of technical beings not as stable individuals with inherent properties, but as a dynamism of restructuring operations which are entangled with their environment. This new temporal, relational ontology of technical beings shares an anti-substantialist theme with new materialism's concept of intra-action (Barad, 2003).

Simondon's unique approach to technical beings is rooted in his deep critique of the alienation between culture and technicity (Simondon, Malaspina, & Rogove, 2017, p. 15). His exhortation to re-integrate technical beings into the web of meaning in the cultural sphere resonates with new materialism's post-anthropocentric stand on harmonious modes of human and nonhuman relationality. The cybersecurity domain can borrow these concepts to critically examine the hylomorphic, reductionist paradigms in computer science and software engineering practice with respect to their effects on software security. The ultimate aim of this paper is to explore a non-instrumentalist, techno-social normativity for cybersecurity research. Software

developers and security engineers can view the maturation of software applications as a process of orienting toward a greater degree of integration, one which resembles the development of living beings.

To develop this argument, in the second section, we will provide an overview of Simondon's theory of 'individuation' in its most general sense – that is, his theory of the process through which an individual develops itself over time (Simondon and Adkins, 2020). We focus on his critique of what we call 'naive hylomorphism,' and examine his view that the traditional concepts of form (*hyle*) and matter (*morphe*) are too static to explain the dynamic phenomena of change and development seen in the world. More specifically, we show how Simondon – in a foreshadowing of the new materialism movement – critiques the common idea that form is the sole active and shaping force in a thing's development while matter is merely passive, inert, and what is shaped. Building on this, we explain the emergence first of vital (biological) individuation, and then of psycho-social individuation (third section). We then take up Simondon's theory of the individuation of *technical* objects (fourth section), focusing on his concept of concretization, i.e., the development of an object from a more abstract stage to a more concrete stage, using an air-cooled engine as the central example. This leads into a discussion of his concept of 'associated milieu,' as exemplified in the traction motor in a train.

In fifth section, we move to the realm of computing and explain how a Simondonian ontology illuminates the individuation of operating systems and software applications as potentially mimicking some elements of the individuation of living beings. We first provide a brief overview of the history of operating systems to reveal the hylomorphic ideology built into the design of modern digital systems. We then use a case study of a malware attack to illustrate that a software application can – like a biological being – become more individuated, more concrete, and more coupled with its technical running environment precisely through being attacked and then responding to that attack.

Simondon's Theory of Individuation

French philosopher Gilbert Simondon (1924-1989) is a unique figure in intellectual history for his lifelong dedication to both philosophy and a detailed, hands-on study of technology. His *Individuation in Light of Notions of Form and Information* (Simondon & Adkins, 2020) presents his general ontological theory of individuation -- how individuals come into being. In this section, we provide a brief introduction to his theory of individuation, explaining four key concepts to prepare for a later discussion of his theory on technical individuation: pre-individual, transduction, information, and associated milieu.

Simondon's main target of critique in *Individuation in Light of Notions of Form and Information* is hylomorphism, a doctrine of being originating in Aristotelian metaphysics, which explains the constitution of an individual being as the union of its 'matter' and its 'form.' In our view, Simondon's critiques apply less to Aristotle's own highly sophisticated hylomorphic theory and more to a simplistic form of hylomorphism which developed later in western philosophy, which we will call 'naive hylomorphism.' This naive hylomorphism understands matter to be a completely passive element of a thing, a pure potentiality to become something different. Under this view, form is the organizing principle which actualizes the potentialities of the matter upon which it is acting. A simple example is a wooden mold (form) used by a brick-maker to shape clay (matter).

For Simondon, however, an individual can rarely exist in a finished form that completely exhausts the potential of its materiality, in part because this materiality is not in fact something purely passive. Rather, an individual is always in the process of inventively developing itself through both its form and its matter, a process which he called *individuation*. If we closely follow the technical operations involved in brickmaking, we see that a sharp distinction between form and matter cannot be maintained. The mold is not a pure form, nor is the clay formless matter. Rather, the mold must be prepared as a form that has its *own* materiality. "In order to produce a form, one must construct a certain defined mold, prepared in a certain fashion with a certain type of matter" (Simondon & Adkins, 2020, p. 23). The clay is matter that *already* possesses a certain form, which is then given a new and different form. Then in a heating process, there is an energy exchange between clay *and* mold. Contrary to

naive hylomorphism, the material of the clay is not passive in this process, but rather expands toward the wall of the mold. The wooden wall of the mold reacts to oppose the pressure from the clay. This exchange of force and energy makes clay into a hardened shape of brick. In other words, what gives rise to the individuation of a brick is the material activity of both the mold and the clay, and the *resolution* of the tensions between those two initially disparate domains of potentialities.

Ingenuity of human labor does play its own part in the emergence of brick, but that labor must work in cooperation with the inventive operations already immanent in both the clay and the mold to bring about a real change. The language of naive hylomorphism cannot grasp this active character of matter; it can only think of an abstract matter and abstract form which are already individuated. To provide a more adequate account, Simondon's theory of individuation emphasizes the dynamic, continuous process in which various forms of individuals emerge from relations between multiple fields of potential. In this process, matter is no longer 'a pile of dead stuff.' Rather, it provides a profound creativity to processes of change, along with the capability of problem solving.

Broadly speaking, Simondon's individuation theory is intended to give ontogenetic accounts of beings at different levels. These include physical, biological, psychic, and social levels of individuation. In all forms of individuation, the same material, operational "formula" is at work. Individuation begins with a system in a primitive state of being called 'pre-individual.' A system in its pre-individual state is abundant with potential and yet does not have a distinct identity. It is "more than unity and more than identity" (Simondon, 2009a, p. 6). That is to say, it contains the potential to begin transformation in multiple directions. Here, Simondon's primary source of inspiration for the concept of pre-individual state of being came from the notion of metastability in thermodynamics. A metastable system is the one that is in an equilibrium which is neither completely stable nor completely unstable. As Muriel Combes summarizes, "a physical system is said to be in metastable equilibrium (or false equilibrium) when the least modification of system parameters (pressure, temperature, etc.) suffices to break its equilibrium" (Combes & LaMarre, 2013, p. 3).

The ontogenetic process begins after an event introduces disparity into the metastable pre-individual system. Then the system begins a series of phase

transitions to resolve the disparity. In each phase of this process, a distinctive kind of individual emerges in the system. This individual, in its structure, preserves some of the potential from the initial pre-individual state, and thus is capable of further individuation.

The growth of crystals is Simondon's paradigmatic example of an individuation process springing out of a metastable pre-individual system. The genesis of a crystal begins in a supersaturated liquid known as a 'mother liquor.' The introduction of a 'germ' – such as a particle – disrupts the equilibrium and polarizes its surrounding mother-liquor. This singular event triggers the process of crystallization, "starting from a tiny germ, increases and extends following all the directions in its supersaturated mother liquor: each previously constituted molecular layer serves as the structuring basis for the layer in the process of forming; the result is an amplifying reticular structure." (Simondon and Adkins, 2020, p. 13)

Naive hylomorphism cannot explain the emergence of such a crystalline structure. The material operation involved in crystallization can hardly be accounted for in terms of a force imprinting a form onto inert, passive matter. In contrast, Simondon's richer conception of matter can make sense of this process, by noting that the operation propagates and amplifies its activity through the very structure it is creating. Simondon replaces the overly simplistic duality of active form and passive matter with the more nuanced duality of 'operation' and 'structure,' both of which actively contribute to the development of the individual.

Borrowing a term from physics, biology, and electrical engineering, Simondon refers to the interaction between structure and operation as *transduction*. In electrical engineering, an example of a transducer is a device which translates energy from one form to another, such as an antenna, which translates radio waves into electrical signals. Simondon ontologizes the general concept of transduction to describe the duality and interplay between operation and structure that is present in any individuation process:

> By transduction we mean a physical, biological, mental, or social operation through which an activity propagates incrementally within a domain by basing this propagation on a structuration of the domain operated from one region to another (Simondon and Adkins, 2020, p. 13).

For Simondon, the concept of form in hylomorphism cannot adequately account for the transductive process, so he proposes that "the notion of form must be replaced with that of information" (ibid., p. 16). By information, he does not mean encoded messages passing from a sender to a receiver through an established communication channel, a narrowly defined concept which came out of the early cybernetics movement. Rather, his notion of information has an operative sense of *in-formation*, namely, the operation of form-taking! In the example of the brick-making process, mold and clay initially exist as two disparate systems. Each system is metastable with the potential to be *deformed*. When the two join together in the heating process, they begin to act upon, or *in-form*, each other. In their transductive exchange, the individuality of the brick emerges when the two systems are eventually stabilized in a new equilibrium. As Simondon puts it, "Information is therefore a primer for individuation" (Simondon, 2009a, p. 10). This reconceptualized notion of information is clearly different from the early cybernetic model of information, which is inherently substantialist in assuming the unchanging individuality of sender and receiver. This model of communication claims that there is a one-to-one correspondence between two individuals that does not structurally change either of them; yet, this is a mathematical myth. The operation of information only emerges in the exchange between "two different orders that are in a state of disparation" (ibid., p. 9) – that is, a state of disparity. Metastability and disparity are the conditions of information. In a real information exchange, as Andrea Bardin summarizes, "there is no univocal transmission, nor a one-to-one correspondence between the systems, but rather we have a concurrent reciprocal influence, and therefore a macro-system composed by A, B and their interaction" (Bardin 2015).

The Theory of Vital and Psycho-Social Individuation

The individuation of *living* beings is based on the same 'interplay of operation and structure' as seen in the individuation of merely physical beings (such as crystals). What is different about the individuation of living beings is that they can do more than merely adapt to their milieu in an external way. A living being actively invents its own exteriority and *interiority*: "the living being solves problems not only by adaptation, that is, by modifying its relation to the milieu, but by modifying itself, by inventing new

internal structures, by inserting itself completely in the axiomatic of vital problems" (Simondon and Adkins, 2020, p. 28). In contrast, during growth of a crystal, the individuating activity only occurs at the ever-expanding surface of the crystal. Its interior does not participate in further individuation. That is, within the crystal there is no true interiority:

> ...the physical individual has no veritable interiority; on the contrary, the living individual has a veritable interiority because individuation takes place from within; inside the living individual, the interior is also constitutive, whereas in the physical individual only the limit is constitutive (ibid., p. 8).

With the invention of interiority, living beings begin to possess the autopoietic character, a power to differentiate the internal and the external. This can be observed in even the most basic form of living being such as a unicellular organism. The membrane selects which elements can be integrated into the interior, and which cannot (ibid., p. 250).

In addition to facilitating the emergence of individuals, the initial pre-individual milieu itself also goes through substantial change. Individuation "does not break the system" (ibid., p. 53) into an individual and a leftover milieu exhausted of its potential. Rather, it introduces a new individual-milieu relation. In the individuation of living beings, there is the emergence of an *associated milieu* as the complement of the living individual. For a living being, its associated milieu is a pathway connecting its interior to a greater domain of being. Through its associated milieu, a living being is able to conserve and renew some remaining potential from the initial pre-individual milieu and carry on the individuation at its own pace:

> ...the principle of individuation…is the complete system in which the genesis of the individual takes place; that, moreover, this system outlasts itself within the living individual as a milieu associated with the individual in which individuation continues to take place (ibid., p. 51).

Moreover, an associated milieu is not something pre-given. Rather, it is invented by a living individual as "a synthetic grouping of two or several levels of reality without intercommunication before individuation" (ibid., p. 383). Simondon often describes the relationship between a living being and its associated milieu as possessing

recurrent causality. The living being creates its associated milieu which, in turn, conditions its existence.

With this view of vital individuation in mind, we can see how *psychic* (psychological) individuation is based upon it. Here, it is important to know that Simondon rejects any substantial separation between the psychic and the vital, emphasizing the continuity between two regimes of individuation. To continue its individuation, a living being engages in vital activities to regulate the relations between its interior and exterior milieu and between what is already individuated and the pre-individual potential. Simondon believes that psychic reality arises from these activities to perpetuate the vital individuation. For example, perception emerges from the vital activities to resolve the conflicts which it encounters with the surrounding milieu. 'Affection' emerges from the vital being's effort to coordinate sense perceptions and actions, and from its effort to regulate the individual-milieu relationship.

The introduction of the psychic domain helps the vital being to maintain its resonance with its milieu, therefore prolonging the vital individuation. But it also poses new problems which a psychic individual cannot solve within itself. When perceptivity and affectivity become incompatible, a psychic individual cannot resolve the problem within itself. It must participate in and be integrated with the individuation of the broader milieu of the collective (i.e., the social) to resolve the tensions and to continue its own individuation. For Simondon, the individuation of psychic beings and individuation of their collective are two poles of *one* process. Between the individuation occurring in the interior of psychic beings and the individuation of their collective milieu which exceeds the individuals, there is a fundamental unity which he calls the *transindividual* relation.

Above we have examined Simondon's theory of individuation in three levels: the physical, the biological, and the psycho-social. He believes that these three levels, in combination, constitute 'nature' as a whole. Now we are prepared to consider how his theory of *technical* individuation relates to and builds off of these concepts.

The Theory of Technical Individuation

Naive hylomorphism is inadequate for understanding the ontogenesis not only of physical, vital and psycho-social beings but also of technical beings. The process of engineering a technical being is often viewed as a direct imposition of a model in the mind of the designer onto inert material elements. Simondon rejects anthropocentric views of technology which tend to reduce technical beings to instruments. For him, an ontological theory of technical objects must trace the dynamical evolutions that take place in their technical lineages through their own necessity and normativity. As Jean-Hugues Barthélémy (2015, p. 20) points out, the individuation of living beings provides the model to reason about the process of technical evolutions.

Levels of Technical Reality

Simondon categorizes technical objects into three levels of existence: the *element*, the *individual* and the *ensemble*. Springs, screws, and transistors are examples of technical elements – simple tools. Technical elements are the carriers of immediate technical operations. A technical element is "free" and "universal" in the sense that it can be integrated into any technical system. When technical elements are organized into a system, the result is a technical *individual*. For instance, an engine is made up of multiple elements or tools. A technical *ensemble* comes into being when multiple technical individuals coordinate through a communications network. An example of a technical ensemble is a factory made up of multiple machines connected via a communications network. But in Simondon's theory of technical evolution, technical individuals are the central focus. At this level of technical reality, the evolution of machines demonstrates an orientation toward a structure which resembles organic beings (Simondon, Malaspina, & Rogove, 2017, p. 60).

Concretization

Concretization is the most important concept in Simondon's theory of technical individuation. This concept describes how a technical object evolves from a more abstract stage to a more concrete stage, i.e., toward coherent technical individuality.

In the abstract stage, different elements of the technical object are linked together but are not fully integrated. The object becomes more concrete when its elements take on a higher degree of structural and functional convergence. Simondon illustrates these concepts by tracing the genealogy of the combustion engine. He observes that in a more primitive engine, "each element intervenes at a certain moment in the cycle, and then is expected no longer to act upon the other elements" (ibid., p. 27). By contrast, in a more advanced engine, "each important item is so well connected to the others via reciprocal exchanges of energy that it cannot be anything other than what it is" (ibid., p. 26).

For Simondon, a higher degree of integration within a technical object has genuinely practical consequences. This greater integration perfects that object by making it more autonomous and more secure. Simondon's language on this point is noteworthy: he speaks of an object's greater integration leading to the emergence of "defense structures" within that object. For example, in the early air-cooled engines, the cooling fins were attached to the engine's cylinder from the outside and only served one function: cooling. The two systems, the cylinder and the cooling system, functioned independently and this meant that the engine lacked integration. But in a more advanced engine, the cooling fins are more integrated with the overall structure of the cylinder because the fins play more than one role. They act as fins to lessen the heat generated by the cylinder but they also act as ribs that "resist the deformation of the cylinder head under the pressure of the gasses" (ibid., p. 27). Concretization is thus the process in which technical beings evolve "into a system that is entirely coherent within itself and entirely unified." (ibid., 2017, p. 29) In this process of evolution, concretized technical objects come to partially resemble natural living beings, even if they can never be identical to the living beings (which are the original concreteness).

Associated Milieu

Concretization increases the internal coherence of the technical object and creates a surrounding milieu for it. This milieu enables a technical object to simultaneously adapt to both the technical and the natural environments in which it is operating. It consists of elements from the natural milieu grouped and synergized with the technical components to support its function. A river dam needs an artificial lake or

reservoir to store water for electricity generation. Simondon calls the kind of milieu that is integrated with a technical object an 'associated milieu.' The associated milieu of a technical object is the necessary condition of the very possibility of its existence. However, Simondon is clear that an associated milieu is not merely a means of adaptation for a technical object. An associated milieu must be invented for a technical object and is also conditioned by it. Simondon describes this co-conditioning relationship between technical objects and their associated milieu as *recurrent causality* (ibid., 2017, p. 60). He uses the example of a traction motor to illustrate the concept of recurrent causality between a technical object and its environment. A traction motor is an electric engine used to propel a train along the track, and it must maintain the speed of a train in as constant a manner as possible as the train travels over a variety of geographical terrains: contours, elevations, sharp turns, etc. A traction motor not only converts electrical energy into the mechanical forces that pull a train on the track, but also adjusts the supply voltage depending on the resistance it receives from the natural environment. In a traction motor, a part of its technical interior must be synergized with the external geographical environment to enable the reciprocal relationship. This relation between the motor and the environment is the associated milieu of a traction motor, the condition of its function (ibid., pp. 55-56).

Although Simondon certainly does not equate concretized technical beings with natural living beings, he sees important similarities between the evolution of technical individuals and the evolution of living beings. Like biological evolution, technical evolution tends toward greater integration by resolving the incompatibility among disparate elements. Like living beings, technical beings stand in relation to an associated milieu. And like living beings, technical beings develop into more mature forms out of an internal necessity contained with them. In other words, for Simondon concretization is not ultimately due to social and economic factors. The functional convergence during the concretization process takes place, in part, due to the non-human factor of an *internal necessity* of the technical being itself (ibid., p. 29). In fact, some human interventions are actually detrimental to a technical object's concreteness. Simondon observes that when many customer requests are imposed on the design of a car, "its essential characteristics are encumbered with external servitude" (ibid., p. 30). In other words, the technical object in such a case has become

less integrated, due to humans failing to bring forth the potential unities that lie within the materials with which they are working.

The reason why Simondon insists upon a non-anthropogenic account of technical evolution can be found in his overall view of alienation in modern age. For him, culture has alienated technicity by reducing it to the domain of mere *usage*, or instruments. Built into culture is a systematic defensive attitude which rejects the possibility of technical beings providing any cultural significance. Simondon found this wall between *kingdom of ends* and *kingdom of means* to be a fundamental blockage in resolving the alienations between humans and alienation between human and nature. He calls for a new technical culture that can "incorporate technical beings in the form of knowledge and in the form of a sense of values" (ibid., p. 15). The first steps toward this reconciliation are to *suspend* the merely instrumental attitude toward technical beings, and to look seriously at the genesis of technical beings in terms of their own intrinsic necessity.

Some scholars have claimed that Simondon's approach has its blind spots. Daniela Voss (2019, pp. 292-296) argues that Simondon has overlooked the way capital and institutional powers shape the form of technical developments. In contemporary cognitive capitalism, new forms of exploitations are often disguised as technical innovations. Without properly analyzing the social and economic dimensions of technical developments, interweaving human life with networked informational devices can develop into new forms of oppressions and alienations. In his analysis of the concretization of social software platforms, Simon Mills (2011, pp. 215-216) argues that "associated milieu [of a social software platform] that is invented and maintained is constructed in association with the regime of the psycho-social and not just that of the physical". To understand digital technicity, we still need to take into consideration social and economic factors as well. As Mills (2011, pp. 224-225) illustrates in his case studies of Twitter and electronic exchange market system, we can further develop Simondon's concretization theory by expanding the concept of associated milieu to social environments. Such inclusion does not contradict his philosophy of nature. After all, Simondon's concept of 'nature' includes all three regimes of individuation: the physical, the vital, and also the psychosocial.

We recognize the strengths but also the historical limitations of Simondon's approach to technical evolutions. We argue that with a broadened concept of associated milieu, along with considerations of the social and economic factors in technical evolutions, concretization theory can still shed light on the nature of contemporary technologies, and in particular the cybersecurity operations of digital environments.

The Individuation of Software Applications

Simondon's theories of biological and technical individuation illuminate the study of cybersecurity in several ways. First, Simondon's arrangement of technical beings as element/individual/ensemble provides a helpful way to conceptually categorize software applications. In the context of software, a digital technical element is a carrier of the most basic computing operations. It can be an instruction in a program, or a system function used by the program during its runtime execution. They are "pure" and "context-free", and can be integrated into any software system. A digital individual comprises a set of organized elements. The most common example of a digital individual is an individual software application such as a text editor, a web browser, or an email server. A digital ensemble consists of a set of individual software communicating through a network. A web-based medical information system, for example, consists of three individual pieces of software: a web browser enabling user-interactions, a web server for processing users' requests, and a database system for data storage. Our focus in this paper is security at the level of individual software applications. An individual software application is a technical individual in a proper Simondonian sense. It is also the central focus of software security. In most cases, security problems do not result from the faults of digital elements but rather from the ways in which they are integrated within the digital individual of a piece of software. At the level of digital ensembles, one vulnerable software subsystem can lead to the compromise of a whole networked ensemble. This has been demonstrated by malware propagation and the recent rise of software supply chain attacks.[1]

[1] In 2020, for example, a group of hackers gained access to the updating server of network management software firm SolarWind and injected malicious logic into the update package DLL of the network monitoring software product Orion. Since Orion is widely used by multiple key departments of the U.S government, it became a "trojan" for the hackers to further compromise the security of these organizations and perform cyber espionage (Rasner, 2021).

Secondly, Simondon's concepts of biological individuation and the concretization of technical beings are helpful in understanding the evolution of software in response to a cyberattack. Each cyberattack such as a malware attack is an informational event in Simondon's sense. It exploits the incompatibilities among the digital elements which software applications base their runtime execution on, structurally deforming them to the brink of disintegration. Unwittingly, a cyberattack also unleashes a chain of security engineering operations which further concretize the vulnerable software. Software applications must reinvent themselves, structurally and functionally, to resolve these incompatibilities. The concretization of a software application is like a vital individuation in that it is an inherently *relational* being and process. Its individuality depends on its relationship with an associated milieu: a running environment called an operating system. The concretization of a software application is always a co-concretization with its OS. Simondon's concept of associated milieu can be applied to investigate the dynamic, reciprocal relationship between individual software applications and operating systems in the context of cybersecurity.

The paradigm of vital individuation is more important in thinking about software security than other domains of technology. Due to the inherent flux of its social and technical environment, software is in a state of metastability. Its internal functional unity is only provisional and is subject to perturbation caused by cyberattacks. Like living beings, software has no choice but to continue its concretization to maintain its integrated form or face total dissolution in the event of a cyberattack.

Case Study

In this section we will use a famous malware attack case study, "Dynamic Link Library (DLL) injection," to examine the cyberattack's effect on the concretization of software applications and their relationship with the operating system. DLL injection is a form of malware attack in which an attacker inserts malicious code into a running process of a software application. Our goal in this paper is not to propose any new security solution, but rather to use DLL injection as an empirical study to illustrate the relevance and helpful insights from Simondon's theory of individuation.

A Primer on Operating Systems

To understand the mode of existence of software, one cannot evade the topic of operating systems as their technical running environment. In this section, we will briefly review the history of operating systems and explain the basic structure and functions of modern operating systems. The goal is to illustrate how the ideology of naive hylomorphism, the alienation between culture and technicity, and the power of capital has shaped the design of the operating system and the mode of its relationship with application software.

A digital object such as a computer program cannot exist without a milieu in which to operate. It might appear as if one physical milieu is the hardware platform on which an application is executing. However, most programs do not directly interact with hardware, because there is a mediator between software programs and their physical milieu. In the early history of computers, running a program was far more complex and indirect than today. While the first generation of computers such as ENIAC had already outperformed humans in the speed of calculation, it still required human operators to manually input the programs into the electronic computer. The early society of the computing profession very much resembled the naive hylomorphic model of labor conditions in ancient Greek society. A 'rational mastermind,' usually a mathematician or scientist working in defense projects, gave a computing task to 'lowly technical operators' and had them compile the concrete procedure of computing steps to complete the task. At that time, it was women who assumed the role of the technical operators (Light, 1999). Female technicians were simultaneously programmers, hardware operators, and file organizers. By outsourcing the 'dirty' work to the female operators, the 'rational minds' could dedicate themselves to much more 'abstract' thinking tasks without being entangled with the 'messy' physical reality of the electronic hardware. Up until the late 1950s, most of the early pioneers of computer programming were women. It is thus not surprising that female programmers made significant contributions to the invention of what is now known as operating systems – an automated version of their own human labors.[2]

[2] One example of this transition from female computer operators to non-human operating systems is seen in the work of Mary Allen Wilkes. From 1959 to 1963, Wilkes designed and wrote the operating system for LINC (Laboratory Instrument Computer) computers, which is the precursor of modern-day operating systems. (Wilkes, 1970)

Immediately after their concrete inception, the subsequent development of operating systems quickly shifted toward more hierarchical structures. With the rise of the modular software engineering approach and the development of high-level programming languages in late 1960s, there was an increasing demand for operating systems to support the concurrent executions of multiple programs and to allow programmers to choose among different programming languages. Operating system design began to adopt a more reductionist approach by separating its core functionality called OS kernel from the users' own programs and from programming languages. Operating systems thus became generic machines which provided more abstract interfaces to the software developers. Software applications became more abstract and more distant from physical hardware. The introduction of personal computers (PC's) and the internet in the 1980s prompted even more complex and diverse demands from PC consumers and business organizations. These demands drastically increased the burden laid on operating systems (Hansen, 2011). A modern operating system must be able to support a large variety of software applications, ranging from 3D video games to web browsers.

To meet the vast and *incoherent* requirements from application software development, a typical operating system today like Windows provides a set of *application programming interfaces* (APIs) for a software developer to be able to use hardware resources more efficiently (McHoes & Flynn, 2010). Suppose a programmer is developing an application, and a part of its function is to store a piece of data on a computer's storage system. Instead of writing her code to deal with the complexity of a solid-state drive, she can have her application call APIs to create a new file, and then write data to the file. As servants to the application, the APIs will handle all the physical tasks of communicating with and controlling a disk drive. Like their human operator ancestors, an operating system hides the messy materiality of a computer and provides an abstract representation of a physical machine to an application program. For most applications and for ordinary human users today, the operating system is the most immediate milieu. Without its support, a computer is merely a collection of raw physical devices. The relationship between ordinary users (including application software developers), applications, a modern operating system, and hardware is depicted in the following figure:

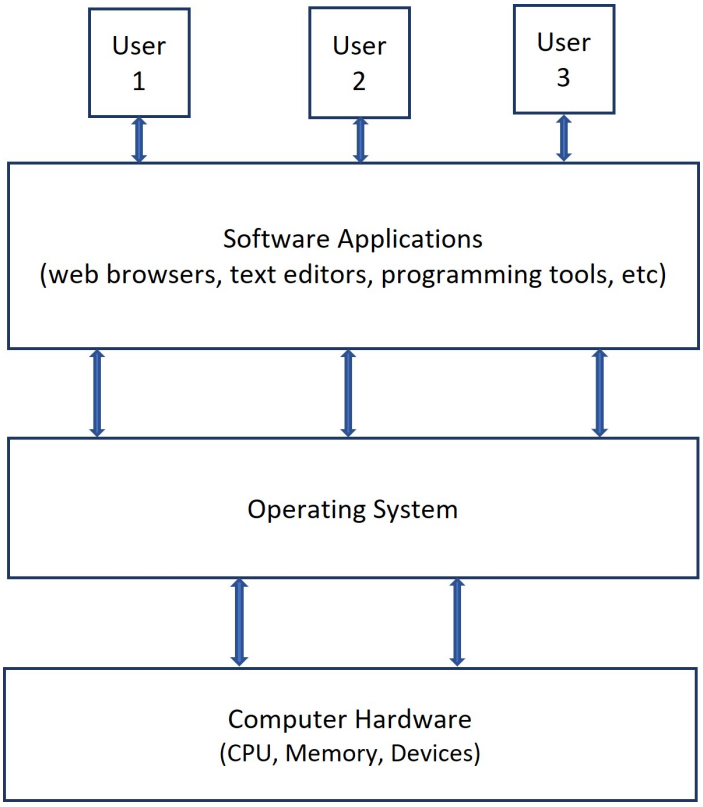

Figure 1. Relationship between users, applications, OS, and hardware.

This allows us to see that modern operating systems have inherited the naive hylomorphic ideology in their very structure. An operating system is a passive '*servant*' which facilitates the execution of a developer's application program without having to know the meaning of the program. When an application program starts running, the operating system will begin a chain of material operations: allocating memory space, loading the application's program code to the memory, preparing the CPU to execute the code, etc. With the operating system's support, software application developers can operate the computer system through APIs without having to know the operations carried out inside the OS. They can dedicate their work on constructing the narrative and meaning at the level of application software – the appearance of user interfaces, the mode of communication among users, etc. The separation between an operating system's internal operations and the application-level software reflects what Simondon refers to as the alienation between culture (apps) and technicity (OS and hardware) in the modern age.

The development of an operating system does not depend exclusively on the hardware and on the minds of the OS engineers. Its development also involves a much larger *social* and *economic* context. Operating systems vendors such as Microsoft or Google have been using APIs as an effective way to attract developers to their platforms. For an operating system, more developers using it means that more software applications are running on the system. This, in turn, means greater market share. In the past decades, there have been API wars between different competing operating system platforms (Spolsky, 2004). How to design new attractive APIs is becoming an integral part of business strategy for many software platforms vendors (Jacobson et al., 2012). Each year, hundreds of conferences are held to attract software developers to learn newly released APIs by various vendors. Communities of developers are built around sets of APIs provided by different platforms. With the enlargement of the developer community for a given operating system, there are also increasing demands to further expand its APIs. An operating system is always incomplete. An operating system and its developers constitute a vibrant, open techno-social system.

As a consequence of these dynamic social interactions, the operating system has become increasingly complex over the last two decades. In each new version of the Windows operating system, there are approximately 1,000 new system APIs added. In the year 2003, Windows XP had little over 2,000 APIs. By the year 2020, Windows 10 has more than 10,000 APIs! In addition to the growth of the API population, modern operating systems also encourage code sharing and modularization. Through the mediation of the operating system, a software application can even share its code with other applications. In Windows, this is done via the use of dynamically linkable library (DLL). A DLL is a program that can be shared by multiple running applications at the same time. From the perspective of software developers, re-using DLLs reduces the programming effort to develop an application. Instead of programming everything from scratch, a programmer can have an application load a DLL during the runtime. For example, when a drawing application needs to print an image during its execution, it can simply request a Windows API, LoadLibrary, to load a DLL specialized for printing and use the program contained in the DLL to complete the task. The same DLL can be shared by various software applications which need to print images. And

one running application on Windows typically loads multiple DLLs during its execution.

Rich APIs and DLLs provide software application developers with greater coding productivity. They are also a means to *control* the community of developers. APIs are the primary means to regulate and settle different demands from developers, and they reflect the will of the majority in the community. However, the techno-social system built around Windows APIs can never reach a complete, stable closure. Due to the incoherent demands from developers, the functions of APIs are often incompatible with one another. The disparities among APIs leave the Windows system in an unstable state. It is in this context of instability that hackers *invent* creative ways of linking Windows' system features and turn it into a dangerous milieu for applications. In the next section, we will visit a classic example of a malware infection technique to examine the relationship between software applications and their milieu. We will show that hackers defy the hylomorphic techno-social order, travelling across the border between application level and operating system level. A cyberattack event is a germ of change. It triggers a chain of operations to secure the system. It brings a whole community of developers and system engineers together to solve a security problem, and their collaborative engineering effort radically restructures an operating system and its relationship with software applications. As a result of this restructuring, a software application integrates a part of the operating system within itself to fend off malware infection, essentially creating a tighter association with the operating system. Cyberthreats and security engineering responses begin to erode the *wall* between software applications and operating systems, thus concretizing both of them, and making their relationship partially resemble the one between living beings and their associated milieus. As we will suggest below, software engineers can cultivate software and its environment in such a way as to increase this resemblance to living beings, and thus increase the level of security.

Study of a Malware Infection Attack

The running activity of an application's code is called a "process" (McHoes & Ballew, 2012). With the support of an operating system, one machine might have multiple

processes running simultaneously. Typical running processes in a Windows machine are file explorer, web browsers, etc. Nevertheless, an operating system as a milieu does not sufficiently protect the individual running process of an application from the harmful behavior of malware. Stealth malware often employs a technique called 'process injection' to inject malicious code into a running process (Monnappa, 2018). [3]

Once it lands in a target Windows machine, malware can use legitimate APIs provided by Windows to inject malicious code into the memory space of a running application and to execute that code. Since the injected malicious code runs in the memory space of a benign application such as Notepad or the Firefox web browser, it can evade anti-malware detection systems. One of the most popular and straightforward types of process injections is DLL injection. The malware first drops a malicious DLL file into the victim's file system. Then, it uses the following four steps to complete DLL injection:

> Step 1: The malware uses a Windows API, OpenProcess, to attach to the running process of a victim application, such as Notepad. The OpenProcess API is by no means a malicious function. It was intended to facilitate system administration. A system administration tool often uses this API to monitor all the running processes in a windows system, profiling their performance and resource utilization.
>
> Step 2: The malware uses another Windows API, VirtualAllocEx, to allocate a piece of memory within the victim process. The malware will then issue WriteProcessMemory to store the path of the DLL to that memory location.
>
> Step 3: The malware uses a Windows API, LoadLibrary, to load the malicious code contained in the DLL file into the memory space of the victim process.
>
> Step 4: Once in the victim process, the malicious code will carry out malicious operations. In some advanced malware attacks, the injected code will delete the malware and the original copy of the malicious DLL file. The whole procedure of DLL injection is depicted in Figure 2.

[3] Process injection attacks have been reported in all three major operating systems -- Windows, Linux, and macOS. We will focus on Windows in this article.

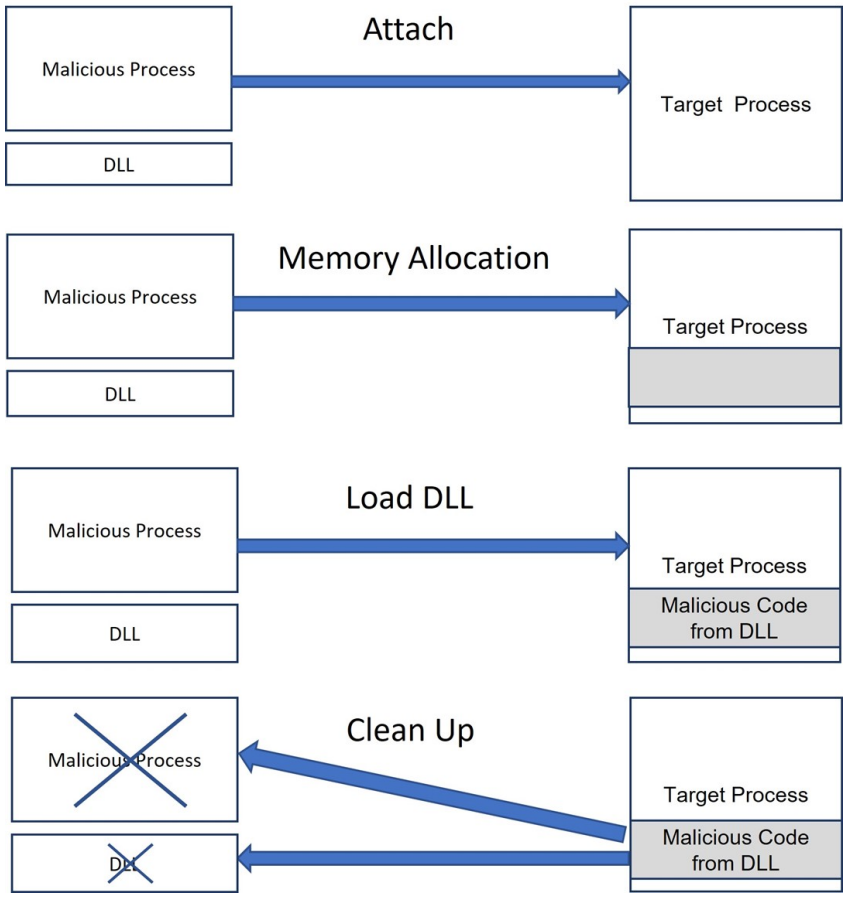

Figure 2. The steps in DLL injection procedure.

Like OpenProcess API, neither VirtualAllocEx nor LoadLibrary APIs are malicious, nor are they insecure by themselves. They are all created as the operating system's routine services to help software developers express their ideas and translate them into material reality at the hardware level! Any software application can use VirtualAllocEx to allocate the memory space that it needs during the execution. Any running software application can use LoadLibrary API to load a DLL that it needs. It is the incompatibilities among them as technical elements and the way in which they are exploited by the malware in its interaction with the target application that cause security problems.

Software Security through the Lens of Simondon

The interaction between a malware and its target program cannot be explained by the early cybernetic notion of information as the transmission of encoded messages from sender (malware) to receiver (target application). From the perspective of this impoverished notion of information, there is no difference between the scenario where two benign software applications are exchanging data and the one where a malware is infecting a target program. Simondon's view of information is that it is a form-taking operation which emerges between two disparate systems, and this view offers a better model to understand the mutual restructuring and deformation between a malware and its victim during the infection.

As the result of the deformation due to malware infection, the victim process loses its concreteness. For example, once the injected malicious code starts running in the memory space of a victim application, it can perform many different types of covert activities. It can secretly collect all the users' bank account data stored in the same operating system and send them to the hacker's web server via a covert network connection. Some malware can even use the infected software application as a host to further propagate the malware itself to other applications in the same computer system or even other computer systems through network connections. In any case of malware infection, injected code lives as a parasite within the process of the original application, causing the original application to lose its functional integration.

To thwart malware attacks, cybersecurity engineers must find ways to protect the functional integration of the software applications running in an operating system. Microsoft, for instance, has created what is called the AppLocker subsystem since Windows 7 (Corio, 2009). With the AppLocker, a software application developer can pre-program a security rule in the code of her application which tells Windows a list of DLLs that the software application is expected to use. When the application begins its execution, its pre-programmed security rule will be sent to the Windows operating system. The Windows operating system, in turn, will use the rule to monitor each DLL the application is attempting to load during the process of its execution. If the application is trying to load a DLL that is not specified in the list, this indicates that the application has been injected by malicious code, and begins to perform a computing task unintended by the developer. For example, if a simple application such as

Notepad is trying to load a DLL for network communication, it is highly suspicious. The system thus detects a potential process injection attack and blocks the execution.

Through the lens of Simondon's theory of concretization, the above cybersecurity engineering method can be seen as a process of concretization. The software application that was previously vulnerable to the disintegrating power of malware gains a greater level of functional integration. This concretization is achieved by inventing a greater reciprocal relationship between a software application and its milieu. Now, the execution of an application reconfigures parts of the OS's functionality according to specified security rules. The reconfigured OS, in turn, safeguards the execution of the application. The operating system is transformed from a generic platform which blindly accepts any application into a more concrete milieu that is more tightly coupled with specific applications. Unlike other domains of technology, software applications run in an inherently metastable milieu. With the ever-increasing expansion of APIs in Windows, one can only anticipate more sophisticated malware attacks will emerge in the future, exploiting the incompatibilities among new and old APIs. For software applications, continuing the concretization is a matter of 'life-or-death'. This dimension of 'existential struggle' makes the concretization in the context of software security closer to Simondon's concept of vital individuation. A software application must perpetually re-invent its interior and re-define its relationship with the milieu in the process of resolving the disparities that are causing vulnerabilities. With the increased association with its OS, the software application gains greater functional unity and is better able to survive malware attacks. In other words, a software application paradoxically maintains its individuality not by being closed up within itself, but by being open to the broader milieu and by participating in the concretization of the whole collective of software, similar to transindividuation in the psychic-social domain.

Conclusion

As this article has shown, a deep understanding of cybersecurity attacks and solutions must rest upon a sufficiently sophisticated general theory of being. More specifically,

such an understanding must rest upon an ontology that is complex enough to account for processes of change that involve reciprocally causal elements and dynamically shifting relations. We believe that Simondon's general theory of ontogenesis is a powerful starting point for such an ontology. His theory not only provides a nuanced account of how technical objects develop over time, but it also proposes the bold idea that, as some technical beings mature, they begin to resemble biological beings in certain important ways. Rejecting the common hylomorphic ontology which reduces entities to abstract form/matter relations, he works to establish an ontology that can account for beings that become more concrete over time by means of their own internal resources and also by means of their reactions to the environment that they themselves are altering. In so doing, Simondon better explains the active dimensions of materiality, the recurrent causality between object and environment, and the dynamic relations of operations and the structures in which those operations act. This general ontology allows Simondon to develop a theory of technical objects which clarifies important aspects of cybersecurity threats and solutions that other theories overlook, such as how a cyberattack (reminiscent of threats to biological beings) can be the occasion for a software application to become more integrated and more secure.

In addition to the engineering insights, the study of cybersecurity can benefit from a new norm of thinking and practicing technology which Simondon (2009b) refers to as the *technical mentality*. This emerging technical mentality has a single criterion: "that of the opening" (Simondon & De Boever, 2009b, p. 24). Secure software development needs to move beyond the paradigm of the automata, the self-enclosed cybernetic "blackbox", and embrace what Simondon describes as *open objects*. An open object is always in progress. It is open to its milieu and to further perfection, like a growing organism. (Simondon, 2014, p. 401). An open digital object concretizes relationally, by penetrating into its milieu like a plant stretching its roots.

Future researchers can build upon this essay, in combination with other research, in several ways. Yuk Hui's *Existence of Digital Objects* deals with the individuation of structured data and metadata (Hui, 2016), while our essay focuses on software processes; an account is needed that would encompass data and software into a larger holistic picture specifically in terms of cybersecurity. Simon Mills' study on the

co-evolution of social software platforms with the psychosocial domain of their users (Mills, 2011, 2016) can also benefit from our study in terms of social software security. With the proliferation of APIs, the social software platforms are becoming unstable and will certainly face more security problems in the future. Our study can provide insights on how cyberattacks affect the individuation of the platforms in relation to both users and application developers.

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MATTER Journal of New Materialist Research

Universitat de Barcelona
http://revistes.ub.edu/index.php/matter/about

Difference-in-relation: Diffracting human-robot encounters

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DOI: https://doi.org/10.1344/jnmr.v3i1.38958

Abstract

This article adopts Donna Haraway's (1992) and Karen Barad's (2007) lenses of reflection and diffraction to probe into human-robot relationships in-the-making. Dominant practices of human-robot interaction aspire to an optics of reflection based on the belief that the differences inherent to machines need masking or assimilating. I propose that diffracting human-robot encounters requires becoming-with and co-worlding with artefacts and their asymmetries. Entering the robot lab to witness my collaborative Machine Movement Lab project and its diffractive strategies in-the-making, as well as the material-bodily knowledges they enact, offers situated insights into how they make tangible difference patterns and relational ontologies at work in our more-than-human encounters.

Keywords

Human-robot interaction; Diffraction; Reflection; Performative practice; Entanglement; Transcorporeality; Performance.

Introduction

Robots will soon be our drivers, couriers, receptionists, soldiers, teachers, nurses, therapists, and lovers, according to—mostly Western—technology-driven futurist narratives. News media commonly offer us[1] a limited binary vision of this future, with social robots either heralding a flourishing revolution (Glinska, 2020) or a job-stealing plague (Taylor, 2019). Granted, nowadays robots are still mostly confined to factory floors and public spectacles that often involve them dancing in unison. Yet major European policy makers already proclaimed that they will transform our society, influencing "every aspect of work and home" (euRobotics, 2013) in the next decade (see also Van Roy et al., 2021). Whether this will remain a (heavily funded) technophile futuristic vision or not, the practices we develop and support, as well as the boundaries, identities, and meanings they enact in pursuing this vision, both literally and ethically matter. They matter because they perpetuate conservative narratives and exclusive hegemonic politics oriented toward wealthy societies that dismiss and demobilise the matterings of both, the less-than-privileged human and the less-than-human nonhuman. Instead, they arrest both bodies and things in mimicry and servitude.

In this article, I will look at human-robot interaction (HRI) as a practice concerned with the making, affirming, and configuring of boundaries between subjects and objects, predicated on fixed notions of the model Human (Suchman, 2011), from the hybrid perspective of my interventionist material-bodily practice and new materialist thinking. From within HRI practice, subject-object boundaries are rarely looked at as a question of production or sociomaterial mattering. Rather, their effects of difference are deemed uncomfortable, in need of being assimilated, at the same time as the identities they engender are being taken for granted. From a new materialist perspective, subjects and objects, in contrast, are neither given nor fixed but rather emerge from the practices of imagining, designing, and enacting human-robot relationships (Suchman, 2007; Treusch, 2020). A number of theoretical works challenge our current visions of human-robot relations with regards to stereotypical gender performances and divisions of labour (e.g., Castañeda & Suchman, 2014;

[1] 'Us' here refers to American and European audiences.

Søraa, 2017; Stacey & Suchman, 2012); and a number of ethnographic studies have explored some of the material effects that these normalised performances produce (e.g., Alač, 2016; Broadbent, 2017; Robertson, 2017). They speak to our onto-epistemological practices and how they inscribe our beliefs and values into our robotic designs, manifesting boundaries that materialise how we differentiate potential human/nonhuman, mind/body, information/matter and subject/object divides. Furthermore, they affirm, evoke, extend, omit or inhibit agencies and, with it, the kinds of relationships that we can have with these social/ised machines, as well as who can have them. Beyond experimental propositions offered by artworks, critical research practices that offer material interventions that counter "restagings of the model Human" (Suchman, 2011, p. 80) are still rare. Pat Treusch's (2020) technofeminist intervention into robotic collaboration, for instance, contributes an alternative, entangled mode of coboting by bringing the sociomaterial dynamics of knitting to the robotics laboratory.

Common HRI approaches with a propensity to restage either the model Human or caricatured versions thereof deliberately shield us from the unpredictable, generative messiness and situatedness of relationships in which humans and machines entangle, dynamically co-constituting each other, and differences make meanings. Such hollow mirrorings of the Human are not only troublesome from an ethico-onto-epistemological viewpoint but also fail to engage with one of the most significant characteristics of human-robot relations—that we can bodily resonate with these machines and kinaesthetically extend into their embodied dynamics and the more-than-human sociomaterial relations they spawn. Participating in this significant potential, however, requires understanding both bodies and machinic things as multiple, porous and always already entangled. The aim of this article is to articulate a counter practice to universalist human-robot configurings by opening up my practice and introducing the material alliances, bodily knowledges and experiential processes that have forged my ontological disposition toward human-machine entanglings. The latter, in a nutshell, embraces the machinic and its differences as more-than-human, promotes an aesthetics of embodied, relational meaning-making (Gemeinboeck, 2021), and understands practice as a becoming-with the material, emergent, always unfinished, and never fully graspable.

This disposition is the heart of my Machine Movement Lab (MML) project, crafted in collaboration with dancers, choreographers, AI researchers, engineers, and numerous material participants (from cardboard, PVC tubes and machinery components to electronic assemblages and software programs), across robotics labs, dance studios, fab labs, and gallery spaces over the past six years. MML is an arts-led research practice that brings together creative robotics, choreography, performance techniques and machine learning, grounded in an enactive, performative framework. It opens up an intimate link to performance-based inquiries into the potential of transcorporeal reconfigurings and harnesses the generative potential of movement and its dynamic qualities to probe into the relational enactment of human-robot encounters. Robots here are abstract, machinelike artifacts, and probing does not happen from outside but involves material-bodily entanglings with the becoming-machine. The more-than-human entanglings allow us to attend to and aesthetically put to work difference-in-relation by fostering a horizontal becoming-with and productive enmeshment of material propositions, kinaesthetic experiences, movement dynamics, and relational affordances. It is this unknowable yet generative tangle of things, processes and resonances from which possibilities for encounter and meaning-making arise. The latter, as we learned over hundreds of variations of entanglings, are the result of the differentiating that is propelled by this generative embroil, producing the interference pattern from which subject-object boundaries emerge.

The relational material-bodily effects of interference patterns mobilised in our MML practice contrast overly simplistic representationalist approaches in HRI that disregard the performative potential of more-than-human encounters. I argue that common HRI approaches are invested in an "optics of reflection" (Barad, 2007, p. 135), whereas a new materialist approach works diffractively by attending to how subjects and objects are mutually constituted and differentially enacted (Suchman, 2007). My discussion of practices of boundary-making is thus framed by Donna Haraway's (1991, 1997) and Karen Barad's (2007) figurative lenses of reflection and diffraction. Reflection and reflexivity "only displaces the same elsewhere, setting up worries about copy and original" (Haraway, 1991, p. 16), whereas diffraction "attends to the relational nature of difference" (Barad, 2007, p. 72), shifting the focus from representationalism to performativity. I begin with discussing practices of reflection in HRI, in tandem with

some of the core beliefs and values that shape subject-object boundaries and, with it, the identities and agencies they manifest, such as gender and other (human) social norms. I then turn to the lens of diffraction to explore how difference patterns arising from the productive interferings that shape our more-than-human encounters materialise as differentiated subjects and objects. In the remainder of this article, I take a closer look at the entanglings and enmeshments that my MML project mobilizes to diffract the human-robot encounter. The encounter here begins with the first design stage and is re-enacted in each interactional situation; it cannot be designed or designed for but rather emerges from material-bodily reconfigurings and resonances, where subject-object boundaries are rendered elastic through transcorporeal bodying-thingings. Hence, instead of designing them as programmable events, human-robot encounters require us to get entangled with and attend to more-than-human interferings and embrace the emerging and multiple.

Reflection: human-robot interaction (status quo)

The "social robot" is a peculiar sociotechnical thing, which often—perhaps more so than others—is deliberately positioned on the boundary between subject and object. This precarious suspension, however, does not manifest itself in imaginative designs that experiment with human-nonhuman divides, but rather commonly gets resolved by making the object look like a subject. While, on the surface, this may appear as breaking down subject-object boundaries, it more commonly serves to echo and reaffirm the differences and hierarchies that this boundary is founded on (Suchman, 2011).

> "Meet Pepper … not your typical robot. […] Pepper is here to make people happy, help them grow, and enhance their lives. Think of it as high tech you can high five […] because Pepper is a friend, an advisor and a business partner – the emotional humanoid robot built to benefit mankind" (SoftBank Robotics US, 2016).

Pepper is one of the most high-profile social robots that we can already encounter in shopping malls or see on television talk shows. The promotional video paints a vision of a near future in which we live and work with robots reminiscent of ourselves—

helpful, polite and gendered—and human enough that we can easily empathize with or "high five" them. Pepper is representative of dominant approaches to developing a robot's relational capacities by relying on superficial qualities, for instance a familiar visual appeal and/or humanlike personality. The latter is supplemented with enormous cartoony eyes, soft shiny curves, head-tilting, gesticulating arms, and a girlish etiquette. It is up to the user to define the purpose of this friendly, humanlike shell and, with it, a role that befits a 1.2m tall robot girl with a perky voice. Although it is worth noting that, according to its manufacturer, Pepper does not have a gender" (SoftBank Robotics US, 2017).

Figure 1. Geminoid F and Jill Bennett, Creative Robotics Lab, UNSW, 2013.

In contrast to humanoids, androids or geminoids present us with a mirror image, which, on the surface, is unashamedly and unnervingly perfect (see Figure 1). Beneath their silicon skin and fluttering eyelashes, they often rely on a human operator to make sense of and connect to the world around them. The android as a phenomenon makes a case in point for Haraway's (1991) "worries about copy and original" and cannot simply be dismissed as a techno-fetish spectacle. It not only manifests age-old,

humanist desires for replicating human life and reiterates dominant assumptions about sex and gender roles (Robertson, 2010) but lends itself to reinforcing hegemonic social norms that "tend to both mirror and embody state and corporate ideologies and priorities" (Robertson, 2017, p. 82).

Many of the current approaches to human-robot interaction get caught up in, what Barad (2007, p. 135) describes as a "representationalist trap" of reflection. The relatively young robotics practice attracts considerable investment into bridging the ontological gap between humans and robots (Guzman, 2020); to mask the profound differences and "deep asymmetries" (Suchman, 2007, p. 11) between humans and machines, HRI research not only "look[s] for homologies and analogies between separate entities" (Suchman, 2007, p. 88) but makes it its mission to model and fabricate them. Given the entirely different mechanical, sensorial, cognitive and behavioural makeup of machines, in tandem with a complete lack of experiences embedded in a society and culture, one would think that no amount of cute or humanlike veneer can render these socialised machines more symmetrical opposites. Yet, the otherness inherent to machines is seen as disrupting pleasant interactions and successful exchanges with them and there is large agreement in HRI communities that it requires softening or obscuring altogether (Sandry, 2016; Castañeda & Suchman, 2014; Dautenhahn, 2013).

The superficial human façade is not only a short-cut, arising from an overly problem- and solution-focused approach and a desire for control (Gemeinboeck & Saunders, 2021), but builds on the belief that humanlike features and behaviours can be orchestrated to program social agency into the machine (Alač, 2016; Jones, 2017). A robot's social capacity is thus considered a property, which is intrinsic to the agent, rather than a matter of enactment, which unfolds through the dynamics of the encounter and the social situation it is embedded in (Suchman, 2007; Alač, 2016). Cut off from the world and equipped with their own autonomous agency, our humanoid companions boldly reflect our "humanist preoccupation with the individual actor living in a world of separate things" (Suchman, 2020, p. 362). Furthermore, understanding social agency as an attribute requires a machine's social qualities to be defined and represented, whether in the form of physical features or programmable behaviours. Behind every individual robotic social actor is thus a designer or a whole team, whose

beliefs and intentions shape its apparently autonomous capabilities and, with it, the relationships it participates in (Mindell, 2015). Importantly, these beliefs and intentions do not only manifest in perky or uncanny features but also material boundaries that delineate who and what matters and whose agencies are affirmed, extended, inhibited or omitted (Suchman, 2011; Treusch, 2020). Robotics practices favouring sameness and mimicry over difference and heterogeneity are thus vulnerable to becoming complicit in affirming and perpetuating hegemonic networks of power.

Rather than attempting to answer the rhetorical question of why we are so invested in the pursuit of rendering our machines as humanlike as possible (Suchman, 2007; Wajcman, 2017), the following sections explore what I believe is a much more interesting question: what if, instead, human-robot relationships are about getting entangled and resonating with something more-than-human to make meaning with entities that dramatically differ from us?

Diffraction: human-robot intra-action (the entangled kind)

Diffraction, itself a phenomenon of the entangled kind, attends to the specificity and materiality of entanglements (Barad, 2007). According to Haraway (1991, p. 300), it is "a mapping of interference, not of replication, reflection, or reproduction". A diffractive approach to HRI thus problematises subject/object and human/nonhuman dichotomies engrained in current robotics research. To get entangled and resonate with machines then requires collapsing the distance between subjects and objects, such as the one produced by a representationalist approach of reflection. Within the context of boundary-making, it is worth reminding ourselves, however, that diffraction and reflection are not opposites (Barad, 2014). Our practices, whether doing HRI reflectively or diffractively, enact cuts that produce separations and effect boundaries; where they differ is a matter of disposition—whether we understand subjects and objects as pre-existing and fixed or as enacted, differentiated-entangled. Thinking and making machines from the (super)position of "together-apart" (Barad, 2014, p. 168) also makes for a differentiated set of possible relations: an entangled approach provokes more entangling.

> Meet the Cube Performer … definitely not your typical robot. You didn't even take note of the box until one of its corners suddenly raised upwards and gradually tilted toward you. The Cube Performer is not here to make people happy; it is here to stretch our imagination and 'become with'[2] something more-than-human. Think of it as a thing you can dance with, entangle with, and be moved by … you don't know what. The box begins to skitter, reaching toward you, then halts, precariously tilts onto one of its corners and slowly sways, as if waiting for you to respond. You are disoriented … then re-orient yourself toward it, sway with it, and find yourself in tune—a tune you will never fully understand.

Figure 2. *Cube Performer #1* with Marie-Claude Poulin (right), AMATA, Falmouth University, UK, 2018.

We built the Cube Performer[3] (see Figure 2), our first robot prototype, after fostering and attending to material entanglings between dance performers and a wide range of materials and shapes for two years (Gemeinboeck, 2021); not to benefit humankind but out of curiosity of what could happen if we quite literally folded humans and nonhumans into one another (see Latour, 1999). Rather than accessorising the robot with googly eyes and pre-packaged emotional mannerisms like Pepper, the Cube

[2] I refer here to Haraway's use of 'becoming with': "The partners do not precede their relating; all that is, is the fruit of becoming with" (2008, p. 17).

[3] Despite introducing my robot in a parallel fashion to Pepper's introduction here, it is worth noting that I do not present the Cube Performer as a 'social robot'. Rather, its purpose is that of a material research proposition allowing us to inquire into the relational-performative potential of machine artefacts and the possible relations they may enact, as well as to engage publics in more-than-human performance scenarios (Gemeinboeck, 2021).

Performer relies on the relational, enactive potential of movement qualities and how they can propel the dynamics of an encounter to participate in it. Movement here is no longer an instrumental capacity but a material, diffractive phenomenon itself, generating interferences and entanglings that give rise to affects and meanings.

Shifting the focus from representation to performativity prompts us to re-imagine a robot's social agency as emerging from the dynamics of the encounter. Agency, in this relational view, is not a property that someone or something can have or be fitted with but rather "agency is a matter of intra-acting … an enactment" (Barad, 2007, p. 178). It is the ongoing "material (re)configurings of the world" (Barad, 2007, p. 151; see also Haraway, 2008; Latour, 2005) through which the boundaries of subjects and objects and, with it, meanings and identities, are differentially enacted (Suchman, 2007). Questions of agency and meaning in HRI design are often taken for granted and amenable to technical reappropriation; determined by individually held representations, the effect of social agency becomes a design feature, similar to an animated character, e.g., expressive eyes, quality of voice, a pre-programmed repertoire of gestures, etc. (see de Graaf & Ben Allouch, 2013; Sabanović, 2010). A designer's intra-action enacting the cut (Barad, 2014) of a girlish voice paired with flowing curves arrests the machine in the performance of a gendered object; it takes a great leap of the imagination to participate in an encounter with Pepper, for instance, that could enact a differentiated identity.

Representationalist/reflective approaches thus seem to confront us with a set pattern, which resists reconfiguring. While diffractive patterns, only revealing themselves to those who seek the entanglement, open up the possibility to become-with, rework and "being reworked by patterns of mattering" (Barad, 2014, p. 187). Yet our relationships, whether human or more-than-human, and their ongoing becoming-differentiating-entangling are of the diffraction pattern of their mattering. There is no outside of the diffraction pattern (Barad, 2014), which also implies that practices of boundary-making and the sociocultural situation they are embedded in are deeply intertwined. Human-robot relationships of the reflective kind with their set pattern thus place themselves outside of the diffraction pattern; they have already ceased to matter, trapped in re-executing the same pattern, over and over again. In contrast, more-than-human relationships of the entangled kind are open for subjects and objects to be

differentially enacted, unanchoring humans and machines from their universalist, culturally neutral categories (Nakamura, 2003).

Doing HRI the entangled way also challenges the Cartesian trap that requires an agent to be autonomous to participate in an interactional exchange. Narratives of machine autonomy deliberately position the designer/engineer outside of the diffraction pattern and its ongoing reconfigurings (see Stacey & Suchman, 2012) and serve to detach the machine from both humans involved and the wider network that the machine and design process are embedded in (Gemeinboeck, 2021). From an entangled viewpoint, autonomy is reduced to an effect, rather than a capacity—the effect of a machine that had its relational network cut off (Suchman, 2007). A diffractive approach thus positions the designer/engineer in the middle of the human-machine encounter, no longer distant to or outside of its matterings and the conditions they arise from.

In the remaining sections I will take a closer look at the more-than-human entanglings that we foster in my Machine Movement Lab (MML) project, the co-worldings they enact, and the new forms of transcorporeal meaning-making that arise from difference-in-relation.

Diffracting the encounter: bodying-thinging

Shifting from a representationalist to a relational-performative view, human-robot relationships are no longer anchored to distinct entities, given agencies and fixed subjects and objects but instead unfold through dynamic entanglings and differentiatings from which meanings emerge. It is important to keep in mind that our more-than-human relationships always already are entangled; hence, diffracting human-robot encounters in practice is not about designing these entanglings but rather about designing-with entanglings (Gemeinboeck, 2021). This distinction is vital as it moves us from a position outside of the encounter, which apparently grants us a view from the top to define and control what unfolds, to a position in the middle of the encounter, where we find ourselves amidst a thicket of more-than-human actants. The latter opens up a more horizontal playground, where meaning-making can only be a matter of enactment rather than control. Diffracting here means designing-with the

encounter, to continuously form alliances between bodies and materials and their relational, affective capacities and aesthetically attend to possibilities as they emerge.

To provide a more situated, material account of the unforeseeable, dynamic encounters this playground opens up, let's briefly step into our dance studio, set up temporarily in a robot lab[4]. Imagine a large space with a few work benches, pushed to the sides; on one of them sits Kaspar, a "child-sized" humanoid robot (IEEE, n.d.), with its small feet dangling over the edge; next to it is a jumble of electronic components, cables, a soldering station, and an oscilloscope. Around the corner, Paro, a fury robot seal (Paro Robots, n.d.), rests on a shelve, surrounded by more tools, cables, and components. The opposite wall looks surprisingly rugged in this environment, dotted with holes and bits of plasterboard hanging off; it is a four-meter-long installation of my artwork Accomplice, turning walls into a noisy, playful machine habitat.[5] As we turn toward the middle of the space, we witness a large cardboard box with a pair of (human) feet, lumbering toward my camera. About two meters away, the choreographer sits on a lounge chair, bent forward and intensely watching the box. I'm standing behind the camera tripod, next to a stack of springy, textile tubes; they used to be foldable garden bins and I still need to tape them together so that we can play with this springy potential.

The choreographer shouts a range of words into the room, they serve as prompts for the dancer, whom the feet belong to … "listening!" … we see the box slowly lifting and twisting sideways, dithering … "question mark!" … "what?", a muffled voice returns, "QUESTION MARK!" … there is a pause, the box gradually lifts, tilted at an angle, seemingly positing layers of time along the way, as if duration could perform a shape, then a sudden shift in gears and the shape accelerates upwards with a twist before it comes to sudden halt. We stop for a break and the dancer thrusts the box backwards and wriggles out of it. When I asked her what she was thinking/doing when she heard "question mark", she said that she did not know, she was just searching, attempting to find a trajectory with the box, struggling to not loose balance. When we looked at the recording together, we saw how the weighting of the box changed along the search for a trajectory; the box clearly participated in the shaping and rhythming of this

[4] Creative Robotics Lab at UNSW Sydney.
[5] Accomplice by Petra Gemeinboeck and Rob Saunders, 2013 (see Gemeinboeck and Saunders, 2016).

performance of a question mark. The bodily processing of what a question mark does, interfered with by the mattering of the cardboard box, and gravity, no less.

We are not interested in what any of these words represent or what performances they shape. Rather, we are interested in how this entangled performance of a human performer and non-humanlike forms with their non-humanlike matterings unfold; how they couple , interfere, or "undo and redo each other" (Despret, 2013, p. 61), and what kind of relations and sensations they co-world. To explore this more-than-human performance, we asked dancers to bodily extend into a wide range of simple, abstract shapes with varying material qualities by entangling with them (mostly from the inside) and moving with them (see Figure 3). We then selected some of these simple geometric shapes to build wearable costumes using lightweight, sturdy materials (e.g., fluted plastic, thin plywood, and aluminium extrusions). The costumes stand in for the morphology of a becoming-robot and its unique spatial-material affordances. They also allow us to trace the kinetic dynamics unfolding in this more-than-human entanglement, which, later, co-shape the robot's machine learning process, where the robot learns to improvise its movements.[6]

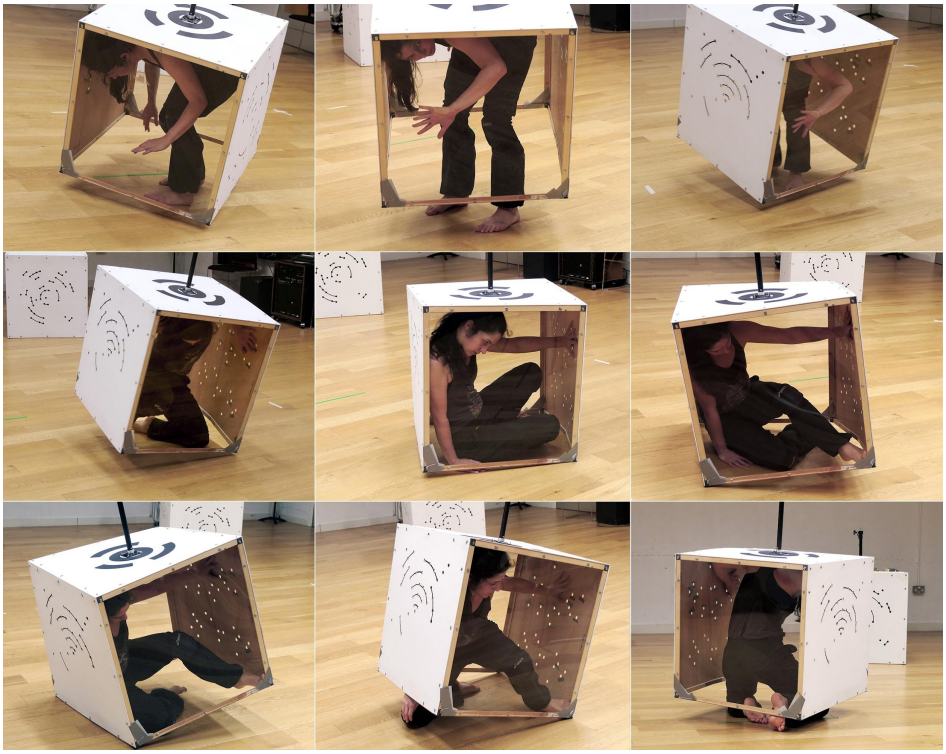

Figure 3. Performer-cube entanglement with Audrey Rochette, 2019.

[6] More details on our Performative Body Mapping methodology, robot design, and machine learning can be found in (Gemeinboeck, 2021; Gemeinboeck & Saunders, 2021).

Sometimes, prompts to propel the entangled performance of dance performer and cube costume (from here on referred to as performer-cube) come from just sounds, their rhythms and dynamic amplitudes, with the choreographer chirping, whistling, or stumping her feet. Other times, they come from experiences one of us brings to the studio/lab, the sensation of a pressure cooker[7], for instance; or a particular material behaviour of one of the costumes itself. One day, I cut openings into a costume (to increase the air flow for the performer inside), and the fluttering motion of the flaps, loosely covering the vertical openings, quickly inspired explorations of breathing-with the costume. Pressing herself against one of the edges of the cube-shaped costume, the performer precariously balanced on one of its corners while raising the opposite corner using varying qualities of speed, weight, and rhythm; the entangled cube rocked forward and upward with increasing haste, culminating in the stuttering, jumpy rhythm-shape of a hiccup. Sometime later, I caught the Cube Performer (our robot) perform a sequence that contained traces of this distinct fragile rhythmic pattern within the context of a dimly lit gallery space and the effect was puzzling. The robot's machinic enactment of what was no longer the same movement—cut together-apart again in the machine learning process—but still had some of its rhythmic qualities rendered the artefact at the same time more strange and more familiar. "Cutting together-apart" (Barad, 2014, p. 168) in loops[8] can make for familiar-strange.

Movement in robotics is commonly a matter of safely navigating space and in HRI also is employed to bestow robots with an expressive character or personality. MML, in contrast, harnesses movement as a dynamic, relational, and generative force, producing the trajectories along which meanings are made and unmade. Erin Manning and Brian Massumi (2014, p. 39) argue that it is movement, which "bodies forth", rather than the body that moves, as common-sense would suggest. As we enact and experience meaning through movement, we make sense of other bodies by resonating with them and their movements (Fuchs, 2016). As Thomas Fuchs and Sabine Koch (2014, p. 1) put it, "one is moved by movement … and moved to move". Meaning-

[7] The choreographer, Tess de Quincey, has introduced this particular image from her BodyWeather practise; in her own words, "the whole point about BodyWeather is to go beyond the biomechanics through images, [that is] we recruit the biomechanics to find ways to move, which are not normally positioned as human movements" (recorded conversation, 26 March, 2015, unpublished).

[8] 'Cutting together-apart in loops' here refers to the iteration of diffracting diffraction patterns that this methodology propels: from performer-cube, motion capture, machine learning and improvisation, to the Cube Performer's resituated, mechanical performance.

making here is transcorporeal (Alaimo, 2010), arising from difference-in-relation. Entangling performer and cube (performer-cube) thus allows us to materially inquire into possibilities for transcorporeal feeling-thinking-with a machine artefact; how we can extend toward it and its uniquely material-machinic ways to relate to the world and how the artefact-in-motion can extend toward us, in return. Movement and its relational, affective capacities give us access to other world-making and fosters an ongoing embodied, playful attunement to the intertwined processes of worlding (Haraway, 2016), a co-worlding.

I look at performer-cube as the first encounter; human-robot encounters do not only happen when a robot design is complete. Rather, I propose, the encounter needs to be understood as a refrain (Stewart, 2010), a co-worlding and becoming-with the becoming-robot that unfolds through the design process and its sociocultural context and is re-enacted in each interactional situation. Dancers, at first, often get frustrated encountering the cube in this entangled way; they try to move "the box" and the box does not let them move the way they would like to; it is only when they begin to re-orient toward the different sensations they receive from the box (its shape; how it bends, where it resists, its weight, etc.) and reconfigure themselves in ways that allow them to become-with the box that they begin to bodily feel-think-with and move-with the box[9]. This is where the difference pattern begins to move and transform; as material qualities are exchanged, prompting reconfigurations and re-worlding; affects emerge and flow across; and the dancer's and the cube's ways of being in the world intermesh; giving rise to co-worlding, the transcorporeal kind. What starts out as a juxtaposition becomes a superposition.

I previously described the effects of this superposition as an ongoing bodying-thinging[10] (Gemeinboeck, 2021). Bodies are always already relational and porous, ready to being reconfigured and, with it, feeling-thinking across other bodies (Alaimo, 2010). The thing's entanglement with the world, in contrast to an object's, has never been completely severed, opening it up to new configurings. Bodying-thinging or thinging-bodying traces the ongoing mutual material attunement to the dynamic

[9] This account is based on conversations I had with collaborating performers, captured in video recordings (unpublished), specifically with Audrey Rochette, 24 November, 2018; 9 July, 2019; and 10 December, 2021, as well as with Sarah Levinsky, 15 March, 2018; and Linda Luke, 24 January, 2019.

[10] Bodying-thinging superposes Manning & Massumi's notion of bodying (2014) and Heidegger's thinging (1975), which unties the thing from an object's utility (see also Grosz, 2005).

effects of the difference pattern that is the encounter and is itself a diffractive pattern moving in synch with cutting together-apart (Barad, 2014) subjects and objects. It speaks to the entangledness and multipleness of bodies and things and their ongoing constitutive differentiatings, undoing and redoing each other (Despret, 2013). Human-robot interaction as an ongoing material-corporeal differing—human-robot intra-action—thus destabilises the engrained dualisms of robotics practices and their manifestations of subjects and objects predicated on the fixedness of bodies and things.

Diffracting the encounter: performing together-apart

Writing about our encounters with companion species, Haraway observes that embodied communication is more akin to a dance than it is to a word:

> "the flow of entangled, meaningful bodies in time—whether jerky and nervous or flaming and flowing, whether both partners move in harmony or are painfully out of synch or something else altogether—is communication about relationship, the relationship itself, and the means of reshaping relationship and so its enacters" (2008, p. 26).

Watching audiences encounter our Cube Performer for the first time, I'm often reminded of Haraway's sometimes jerky, sometimes flowing dance; with dynamics that unfold in unpredictable configurations and participants finding themselves, alternating, in moments of harmony or 'painfully out of synch' with the cube artefact. The encounter is a dynamic diffraction pattern itself, with humans and machines moving in phase, then out of phase, and back into phase. In phase, we are bodying-thinging with the thinging-bodying of the artefact, bodily resonating with the relational, affective qualities it enacts. We are drawn into… whatever this is. Then something jars, the flow begins to stutter, and we might suddenly notice ourselves dancing with a box: out of phase again. The goal is not to stay in phase but to keep dancing, undoing and redoing each other, and to remain open to what unfolds.

Figure 4. Performing together-apart with performers Katrina Brown, 2019 (left) and Audrey Rochette, 2020 (right).

Our second project stage of diffracting the encounter extends to performance-making with human-machine interference patterns, involving various configurations of entanglings, e.g., a Cube Performer with one (human) performer; a performer-cube with a Cube Performer, or two Cube Performers. Building on the first encounter stage, performance-making here is rooted in an ontology of becoming and focuses on aesthetically attending to expanded notions of encounter (beyond performer-cube) to foster entanglings of entanglings (see Figure 4). Similar to the first stage, we are interested in the emergence of new relations and any meanings they may acquire, rather than choreographing the encounter or any dynamics that may unfold. Giving ample space to co-worldings and bodying-thingings, I found, is best done through improvising with the material minglings as they arise. Let's briefly step back into the studio; this time a dance studio[11], which is mostly empty apart from two tables and four chairs, the Cube Performer (robot), some tools we brought with us for any maintenance needs, and four tall stands elevating motion capture sensors that mark out a five-by-four-meter playground for the matterings of performer-cube.

As we step in, we witness the performer kneeling on the ground in front of the cube costume, coupling herself with the cube by placing her right hand underneath the

[11] University of Applied Arts Vienna.

bottom edge closest to her. Her kneeling posture refigures her body's kinesphere[12] to align with that of the cube; she carefully lifts the edge and begins to shuffle sideways, sliding the cube along with her, while taking care that they remain tightly coupled, facing each other the same way as they started (with the cube having four equal faces, "facing the other" is a fluid matter). The two appear to be moving together, rather than one being moved by the other. She softly places the cube's edge on the floor, pauses, and tilts the cube upwards to slip into it. Next, we see the cube lifting the opposite edge with slightly more weight than we saw earlier, and performer-cube shuffle-slide along a trajectory very similar to the previous scene. Interestingly, the cube still appears to face something or somebody; it is the ongoing material attunement that supported the coupling and "facing each other" earlier, now re-enacted by performer-cube, that refigures the omnidirectional geometry of the cube and renders it relational, extending toward … something (elsewhere).

The above experiment is part of a sequence of explorations that began with the image of a ventriloquist performance. Initially, the choreographer conceived of the image of a ventriloquist's relationship with a puppet because she struggled with the notion of a cube (on its own) being able to actively participate in the encounter and enaction of agency[13]. The image allowed her to kinaesthetically probe into a power constellation that transfers agency to a 'thing' (and the possibility to reverse the direction of transfer) from both the ventriloquist's position and that of the puppet. I was concerned that this problematic premise of agency shifting between a body and a thing (rather than emerging in-between) would disentangle performer and cube by addressing and, more so, foregrounding them as an already formed subject and object. Once performer-cube began to improvise with the image, in tandem with choreographic instructions for finding different points of attaching and mapping between, however, we witnessed increasingly porous performances of together-apart, rather than transactions of power between a given subject and object. We learned from the performer that, when outside, she used the points for coupling herself with the cube to extend herself into it, and, when inside, reoriented-with the cube to the same lines (for extending into), now in

[12] The term kinesphere was coined by Rudolf von Laban (1966), referring to an imagined sphere around the body that it can easily extend into without changing position. Given that both the robot's and costume's bodiness emerge from movement, we attend to the cube's 'body space' in relation to its extended potential as body-in-motion.
[13] My account of our process is based on video documentation material from 1-9 July, 2019, and the choreographic notes from choreographer Marie-Claude Poulin, 2 June, 2020, and 21 December, 2021 (unpublished).

reverse, to extend-with the cube beyond it[14]. This is cutting together-apart (Barad, 2014) along transcorporeal "lines of flight"[15] (Deleuze & Guattari, 1987, p. 3).

The more we transcorporeally extend into and resonate with the difference pattern, the more it becomes meaningful. Developing a more horizontal (play)ground for enacting human-machine relationships, I believe, has thus much to do with our ability to extend into the other's world (Alaimo, 2010). Mirroring façades in HRI not only reflect back what we already know but also conceal the difference patterns at work beneath the façade. A robot's perception of the world, for instance, like its embodiment, radically differs from human perception, no matter how humanlike or machinelike it looks. Hence, as humans and robots entangle, they are, from a biosemiotic viewpoint, each embodied in their own unique umwelt (von Uexküll, 1957; Ziemke & Sharkey, 2001). We are bodying-thinging across differentiated ecological niches. To foster performers' ability to bodily feel-think-with the robot's umwelt, we expanded the cube costume to include the Cube Performer's machinic sensorium. The sensed data, dynamically mapping surfaces and relative distances in the cube's surrounds, is made tangible to the performer in the form of a dynamic soundscape. Dancers like to make use of their cube entanglement to play this soundscape like an instrument, reshaping it with every move; what is performed here is intra-action at work: performer-cube co-world refigurings of the soundscape and the refigured sounds, in turn, reshape the unfolding performance of co-worlding. Entangling the dancer's and the machine's umwelts thus allows us to extend into the robot's world-making and aesthetically attend to the difference pattern of their respective worldings.

Diffracting the encounter: toward human-robot experience (HRX)

Diffracting the encounter in-the-making and, with it, human-robot relationships, we also need to attend to the built-in hierarchy between designers/manufacturers and so-called users. Designing robots and imagining the relational scenarios in which we encounter, work, or live with them[16] requires a much wider participation of a much

[14] Based on video documentation material from 1-9 July, 2019, and an interview with performer Audrey Rochette, 9 July, 2019 (unpublished).

[15] In French, *ligne de fuite*; in Notes on the Translation (Deleuze & Guattari, 1987), Massumi notes that *fuite* not only relates to notions of fleeing but also flowing or leaking.

[16] It is worth noting that my notion of 'social robots' refers to robotic artefacts designed to participate in or operate within social scenarios, including domestic spheres, workplaces or artistic contexts.

broader range of actors, most of whom are currently excluded from the making of our sociotechnical futures. I recently started a four-year research project to develop performance-based participatory strategies for opening up[17] this diffractive practice to a much broader range of design participants; to engage possible future stakeholders in bodily-feeling-thinking-with machines that do not reflect the model Human and a sociocultural context that is not and never will be theirs. After all, most stakeholders of the social futures that our technical imaginaries seek to shape are not to be found in robot labs. I call this practice human-robot experience (HRX) to both, align it with the familiar practice of HRI and, at the same time, deviate it from the simplistic interactional transmission model oriented toward autonomous agents, which much of HRI builds upon.

Figure 5. Robot design workshops with school children at AMATA, Falmouth (left), and The Exchange Gallery (right), UK, 2018.

My HRX practice builds on and significantly expands our robot design workshops with children (Gemeinboeck & Saunders, 2021) that revolved around playful mock-up scenarios in which they invented new kinds of human-robot relationships by undoing and redoing subject-object boundaries using simple cardboard boxes and an array of arts and crafts materials (see Figure 5). Building on performance and theatre techniques, the main focus of HRX is to engage participants in bodily-material enactments of their own human-robot encounters, instead of the Cartesian hall-of-mirrors we are currently given. Participants will be invited to develop their own co-worlding scenarios, in tandem with bringing/selecting materials and designing-with

[17] The Cube Performer's making, learning and performing have so far been situated in a relatively singular sociocultural context, despite the project spanning across three continents and involving eight performance practitioners and five researchers and their different backgrounds and experiences.

and bodily-feel-think-with their own machinic forms and sensorial soundscapes to connect with a robot's particular world-making and negotiate emerging interference patterns. Traditionally, HRI labs open their doors to people from the outside to 'test' their experiences with already designed robots within the context of a tightly orchestrated, fixed study frame (Sabanović, 2010), rather than inviting them to co-design their own, entangled experiences. I believe that a much wider public access to more open, rich, bodily in-situ experiences of the transcorporeal possibilities and interferences at work in our encounters with robots, before we begin to manufacture them, is key to making a difference in how we envision our sociotechnical future.

Diffracting the politics of human-robot interaction: concluding remarks

The article's main proposition is that diffracting human-robot encounters requires becoming-with and co-worlding with artefacts and their asymmetries. Dominant HRI practices, in contrast, pursue an "optics of reflection" (Barad, 2007, p. 135) based on the belief that the differences inherent to machines need masking or assimilating. My collaborative Machine Movement Lab (MML) project develops a counter approach to this reflective practice; building on Barad's (2007) concept of agential realism and a performative-material understanding of movement, we attend to the relational enactment of subjects and objects by aesthetically putting to work the difference patterns at play in our more-than-human encounters. I explored how our performative, material strategies for diffracting human-robot encounters bodily enact human-robot co-worldings and attend to the transcorporeal resonances of their interference patterns to mobilize subject-object boundaries. It is these performative strategies, the situated material-bodily knowledges they enact, and how they aesthetically attend to and make tangible difference patterns and relational ontologies at work in human-robot encounters that I would like to contribute to the unfolding discourse of new materialist informatics.

The political potential of this new materialist artistic practice is that it materially mobilises an ontological disposition toward entangled human-robot configurations by opening up ontological boundaries to bodily-material reconfigurings. The transcorporeal entanglings that MML provokes challenge hierarchical dualisms still engrained in HRI and the limited humancentric ways in which we envision our robotic

futures by reorienting our bodily ways of knowing and attending to the performative potential of the encounter. Subjects and objects, bodies and things, humans and nonhumans here are no longer fixed, universalist binaries but are entangled, multiple, and porous; constituting and reconfiguring each other and effecting transcorporeal resonances through the diffractive attunement of bodying-thinging. Experiencing more-than-human co-worlding 'through the looking glass' rather than distorted reflections of the model Human, I believe, could open up pathways toward a horizontal ethical playground for humans and machines. Furthermore, the Cartesian politics that delineate subjects and objects are the same at work in designating the model Human; a horizontal-diffractive playground could thus lend itself to opening up human-robot relationships and how we enact them to a much wider range of actors to foster more diverse and multiple visions of our robotic future. After all, to participate in this more-than-human playground, our relationships with machines do not require diffracting (they always already are); instead, they require us to not conceal the "patterns of difference that make a difference" (Barad, 2007, p. 72) by masking them with reflection patterns. They hold us at a distance and keep us from entangling and becoming-with machines. And dance with them.

Acknowledgments

This research has been partly supported by the Australian Government through the Australian Research Council (DP160104706 and FT190100567); the Austrian Science Fund (FWF, AR545); and the EU Framework Programme (FP7, 621403).

Many thanks to my collaborators for their invaluable contributions: Rob Saunders (Leiden, NL), Roos van Berkel (TU/e, NL), Maaike Bleeker (Utrecht, NL), Katrina Brown (Falmouth, UK), Rochelle Haley (UNSW, AU), Lesley van Hoek (NL), Sarah Levinsky (Falmouth, UK), Linda Luke (*De Quincey Co*., AU), Dillon McEwan (AU), Kirsten Packham (AU), Marie-Claude Poulin (Applied Arts Vienna, AT), Tess de Quincey (*De Quincey Co*., AU), Audrey Rochette (CA).

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MATTER Journal of New Materialist Research

Universitat de Barcelona
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Articulating Nomadic Identities of Radio Signals

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DOI: https://doi.org/10.1344/jnmr.v3i1.38959

Abstract

This article presents a new materialist approach to artificial neural networks, based on experimental research in categorization of data on radio signals. Picking up on Rossi Braidotti's nomadic theory and a number of new materialist perspectives on informatics, the article presents identification of radio signals as a process of articulating identities with data: nomadic identities that are informed by all the others, always established anew. As a resistance to the dominant understanding of data as discreet, the experiments discussed here demonstrate a way to work with a digital archive in a materialist and non-essentialist way. The output of experiments, *data observatories*, shows the capacity of machine learning techniques to challenge fixed dichotomies, such as human/nature, and their role in the way we think of identities. A data observatory is a navigation apparatus which can be used to orient oneself in the vast landscape of data on radio transmissions based on computable similarity. Nomadic identities render materiality of radio signals as digital information.

Keywords

Radio signal; Digital archive; Nomadic theory; Machine reason; Identification.

Introduction

What we know about radio signals spans different domains of human sensibility and legibility. For example, a communication engineer knows how a signal 'sounds' in its demodulated form, or what its spectrogram looks like. More importantly, they know how the signal works, how information is modulated on the carrier wave, and at which frequency it occurs. A perspective from information studies might seek to identify patterns in data on signal properties and organize this knowledge in the archive. A feminist data scientist might problematize these archival practices, looking into the way differences across signals have been (or not) naturalized, land the lack of representation of certain types of transmissions, or certain archivists in the archive (D'Ignazio & Klein, 2020). A media archaeologist interested in media ecology might trace the material history of radio signal transmission technology and its biological-technological codetermination (Parikka, 2010). In this text, I discuss a specific intersection of radio signals onto-epistemology: what the signals are and what we can know about them in connection to engineering, international relations, media theory, and sociology. While this article can claim none of the academic fields it visits as its own, it seeks to frame the problem of the conceptualization of radio signals as an interdisciplinary problem that relates and connects different disciplines, without reducing them to any single dominant view.

New materialist attention to radio signals emphasizes the inadequacy of fixed oppositions (i.e., human/nature), and singular disciplinary perspectives, to host sensorial and cognitive coupling with radio signals. This article suggests no direct access to the materiality of the electromagnetic medium. Instead, new materialist interest is articulated here through an engagement with the digital data on radio signals. The materialist approach is reinforced with one important characteristic of the dataset: it documents real, situated radio signal transmissions. Radio signals are transmitted and received by technical equipment, which is built based on techniques of ideal energy propagation and information encoding. Unlike ideal transmissions, the recordings of signals are shaped by contingencies in the process of propagation through the environment. The transmissions are situated by the virtue of being recorded by specific people, using specific equipment, on specific locations on Earth, and the decision to include them in the database, such as the Signal Identification

Guide [SIGID] wiki[1]. This archive gathers recordings and other information on radio signals heard across the planet, documented by voluntary contributors.

Radio signals matter to the emergent field of new materialist informatics in two distinct ways. First, the origin of radio signals can be natural emissions or human-made transmissions. Hiss, Whistler, Dawn or Auroral chorus[2] are some of the names given to naturally occurring electromagnetic phenomena that can be 'heard' with specific receiving equipment. In *Earth Sound Earth Signal*, Douglas Kahn challenged the distinction of nature and culture in the instrumentalization of radio signals, on the premise that media (as in telecommunications media) do have nature and are underdetermined (Kahn, 2013). Jussi Parikka focused on the joint history of media and nature to tease out senses and rationalities inherent in the logic of life and technic, as in 'bio-logy' or 'techno-logy' (Parikka, 2010). In this parallel between media and nature, Parikka creates room to discuss natural technics in the context of organization and architecture, such as insects-builders or self-organized swarming systems. A new materialist media theory recently proposed by Vera Bühlmann, engaged Michel Serres' philosophy of natural communication to speak of mediality of public knowledge (Bühlmann, 2021). The double articulation of time as/in space, of physics of communication as a communication of physics, requires attending to materiality of time that passes (commutes), to its communicative materiality. In the ways highlighted here, technicity and communicative capacity of radio signals are expressed as nature, but also have nature. Radio is not passive energy waiting to be put to use, but active energy, whose materiality unfolds in time and space.

The second aspect of radio signals that is relevant in new materialist informatics is their inherent technicity: humans can experience radio only with mediation of transmission equipment, and this equipment is increasingly digital. Having no sensorial access to electromagnetic phenomena, we must rely on acoustic and visual representations of signal's frequencies to analyse and identify the transmissions. Communication engineers and people with related expertise can identify patterns, signatures and tonalities in demodulated audio samples and signal spectrograms.

[1] Signal Identification Guide wiki is available at: https://www.sigidwiki.com/ Accessed Jan. 26, 2022.
[2] For an overview of techniques and practices of the reception and study of naturally originating radio signals, see *Radio Nature* by Renato Romero.

The necessity to combine faculties of sonic and visual knowledge, speaks of the spectrality of informational content in radio signals.

The invention of an affordable and accessible system for radio signal reception on a personal computer, RTL-SDR[3], motivated the community around open-source mobile communication to start collecting and sharing techniques for observation and identification of environmental radio transmissions. The practice of radio observation is similar to bird watching or other wildlife observation, with the important difference being in our incapacity to actually perceive wildlife with no or minimal support of technical equipment. Radio signals, as previously mentioned, require sending and receiving equipment to operate under specific conditions in order to capture signals and enable their observation. The combined interest of radio enthusiasts and hardware hackers brought rich digital archives of data on radio signals online. The SIGID archive, which is the basis for computational experiments described in this article, is accessible to anyone with a connection to the internet. While the data is organised in a clear and legible fashion, a non-expert may still find the information on radio signals difficult to navigate.

In addition to exploring effective ways to organise digital data, the research in digital archives of radio signals problematizes what is sometimes referred to as 'digital literacy' (Colman et al., 2018; Vee, 2017), namely how computation and networks work and how we can develop skills in working with them. While the approach to computation in the past fifty years remained techno-solutionist, that is focused on solving whatever problems one was given with technical means, a digital literacy would in principle enable one to articulate different expectations from computing, which are non-essentialist and non-instrumental. I experiment with machine learning algorithms in order to challenge instrumental categorizations of technical artefacts, such as radio signals. Inspired by feminist critiques of technoscience, I propose to work on becoming skilled in using these advanced computational techniques differently, as one possible mode of resistance. This article gestures at possible ways for doing so.

[3] Engineers gathered around open-source mobile communications project (osmocom) found a way to turn small USB dongles, made for digital television (DTV) reception, into computer-based radio scanners. They hacked the driver on the RTL2832U chipset and found a way to access the raw IQ data from the analog to digital converter, which samples the radio frequency space. The tuner on the DTV device can tune in a wide range of frequencies. https://sdr.osmocom.org/trac/wiki/rtl-sdr (accessed 17.02.2022)

This article establishes intersectional connections between the work of machines and people – in terms of knowing and finding patterns. In the text that follows, I discuss the design and engagement with computational artefacts, *data observatories,* which stand for the method and ambition to organise radio signal data according to properties that come from the dataset, for articulating the archive in its own terms. Signals are computationally described and compared in terms of properties that are shared across the entire dataset. By encoding the data in this way, the signals get an informational face, a sort of nomadic identity. This identity is not universal or fixed, but mobile and changing depending on how we are looking at it. These identities tell different stories of connectivity, of its entanglement with computation and archiving. Situating computational identities of radio signals through a programming praxis aims to develop their partialities, not universality, opening up the way to insights which are complex, contradictory, structuring and structured, not from outside but from within.

What is Materialist about Materialist Informatics?

Radio signals which I discuss here manifest as 'weird' materiality when portrayed within the classical human/nature divide. In Parikka's articulation of new materialist concerns as media theory, weird materialities designate that which escapes direct human perception, and is irreducible to categories of 'soft' or 'hard'[4] (Parikka, 2012). Radio signals are 'simply' energy, but they have a material and symbolic importance for human societies, both as environmental radiation and as messages they transmit. I will trace three approaches to the question of informatics in (new) materialist scholarship, through the weird materiality of radio signals.

Iris van der Tuin acknowledged that working in new materialism while "living in networked societies and experiencing ecological changes in our everyday lives revitalizes the question of subjectivity" (Van der Tuin, 2014, p. 233). In her exploration of new materialism with Rick Dolphijn through cartographies and interviews, van der Tuin affirmed new materialism's capacity to challenge the authoritative gesture that

[4] Parikka specifically refers to Serres' distinction onto 'soft' and 'hard' as two polarities which for Serres are indeed in a continuum, contrary to Parikka's reading in the text referenced here (Parikka, 2012). For more on the continuity of 'hard' and 'soft' in Serres see (Bühlmann, 2020). Parikka's interpretation is based more closely on Serres articulation of pollution in *Malfeasance: Appropriation Through Pollution?,* while materiality of communication and communication physics for Serres are based on the irreducibility of communication or physics to hard and soft.

takes apart the material and discursive in an overly confident logic typical for Enlightenment (Dolphijn & Van der Tuin, 2012). Dolphijn and van der Tuin traced the specific approach to materiality at stake in feminist new materialism. New materialism, they assert, is a practical philosophy, which entails the affirmation of the thinking process as material. Such philosophy shows us one possible way to address radio signals as material and discursive artefact at once, to approach their 'weird' materiality.

Haraway's take on materialist informatics pointed to the inevitability of living in relationship to standards and regimes that are not one's own (Nakamura & Haraway, 2003). The dominance of techno-economic systems facilitates propagation of universal categories of 'human' and 'machine', unresolved in her original take on the cyborg, while reinforcing the impossibility of walking away. This is important to recognize so that one can think of other ways of doing life, while remaining "always inside complex material semiotic worlds and not inside these universal categories" (Nakamura & Haraway, 2003). For Haraway, language is material and she is interested in its materiality as specificity. For example, she recounts in the interview with Lisa Nakamura, how she appropriated the term Cyborg from space-race language, in order to infuse the technical imaginaries with that of social reality of women in her influential Manifesto (Haraway, 1987). This act of appropriation demonstrates the power of language to inscribe practices and new matter-realities through concepts. My approach to knowing radio signals is informed by Haraway's and numerous other feminist scholars' refusal of universal categories and insistence on situating oneself within complex webs of knowledge. Precisely by undoing clear, pre-determined distinctions between radio signals and nature, but also across signals themselves, identities can be articulated in informational terms, in terms of the digital archive of radio signals.

For Felicity Colman, materialist informatics should be specially concerned with the image. She develops new materialist considerations for "the image as a mattered aesthetic intra-active affective measure" (Colman, 2014, p. 13) in feminist theory and practice, and following Barad's notion of intra-actions (Barad, 2007) proposes to understand an image as "an aggregated concept […] a material thing that is the result of a series of relational positions, the centre of which is a body" (Colman, 2014, p. 9).

The image is an important mode of communication in the digital field. It can also provide focus. Colman reiterates the concept of identity with the image, with new-materialist feminist attention to naming, predication, and mediation. Such attention to image as identity is precisely opposite of representation, and lends itself well to reimagining the archive of radio signals. Trying to capture materiality of the image through mediation and searching for markers, Colman suggests to look at the body as a platform capable of mediation, a medium and a media. “We can use the discursive matter of feminicity to articulate the living capital body – as image and as a materialized informatics – involving identification of the predication of feminicity and, indeed, of masculinity, unicity and other technicities” (Colman, 2014, p. 13). Colman’s material treatment of the image which captures and focuses (digital) information suggests the possibility to both render and access materiality of digital archives, which will be explored in this article.

Nomadic Identities: Challenging Classification

To question classification is a feminist concern: how are people divided in categories of gender; how is an identity articulated and performed, with regards to its other. With the specific explorations of a radio signal dataset that I practice and discuss here, I strive to challenge conventional dualisms and classification as normative modes of thinking, perpetrating a singular logic of the world: for example, the logic of a radio amateur’s fascination with communication engineering. The current practice for identification of radio signals engages closely with conventional, instrumental classification. A signal is described in terms of its capacity to transmit information in military communication, in navigation, or as part of amateur radio spectrum. To counter this, I propose to pay attention to nomadic identities of radio signals, always made anew through computational comparisons across a database of recordings of different radio transmissions.

Nomadic theory of Rossi Braidotti makes an important proposition that resonates with the materialist concern for radio signals identities that I develop here. To speak of nomadic subjectivity is for Braidotti “an act of resistance against methodological nationalism” (Braidotti, 2011, p. 7), which might be useful to challenge classical

mobilization of differences in dialectical opposition and mutual consumption towards an interconnected scheme. Nomadic subject resists “deterritorialization” in Deleuzian terms: the mobilization of difference and estrangement from the familiar or intimate social identity. It engages a rhizomatic logic of zigzagging across interconnections. For Braidotti, being nomadic is clearly “not a glamorous state of jet-setting” (2011, p. 10) but to the contrary, the difficult and strenuous process of critical relocation, of grasping and disclosing one’s situatedness, “speaking from somewhere specific and hence well aware of and accountable for particular locations” (Braidotti, 2011, p. 15). A nomadic subject is a sustainable subject, open to intense flows of desires, almost to the point of breaking (Braidotti, 2006). This sustainable subject position is available to the reader anywhere at any time, or as Katherine Hayles positions Braidotti’s posthumanism: it is a way of being, it is transhistorical and non-technical (Hayles, 2018). This is important when considering its capacity to challenge classical taxonomies and ordering increasingly performed by technical/informatic systems. Could we update Braidotti’s nomadic theory to address materiality of neural networks and classification algorithms?

Databases and digital archives provide lists and system of details that document the lives of plants and animals, natural and social phenomena, behaviours and observations. Everything we encounter appears already categorized in some way, which propagates the presumption that these categories are meaningful in themselves. Tahani Nadim wrote critically of databases as providing more than comprehensive lists. She pointed out how the Fauna Europaea zoological taxonomic index of European animal species: “constructs a naturalized image of Europe (Nature’s supernation, if you will), […] it confirms the continued relevance of natural history collections, and it translates the taxonomic gaze—with all its (colonial) blind spots—into a symbolic calculus (species-as-assets)” (Nadim, 2021, p. 128). Databases, such as the radio signal digital archive are not passive containers of data. They facilitate certain rationalizations while hindering others. They are historically specific, practically different and their context matters. This resonates with contemporary feminist critique of database ontology, its singular logic of representing the world, carefully traced hierarchies and exclusions. The authors of a cultural studies article on tagging noted that: “within databases […] we construct categories of normativity, singular ways of commanding the logic of the world” (Juliano &

Srinivasan, 2012, p. 619). From a related media-theoretical position, Posner and Klein question the meaningfulness of categories in archives and connect to feminist theory (in particular the work of Butler, Haraway and Barad) to “challenge the repressive systems of classification” (Posner & Klein, 2017, p. 4).

Intersectional feminism poses important questions to methods for working with data and classification. In *Data Feminism*, Catherine D’Ignazio and Lauren F. Klein (2020) engage with intersectional analysis of the ways in which systems for counting and classification perpetuate oppression. They recognize an initial impasse: to be put to use, data must be classified in some way. This builds on well-known work of Bowker and Star (2000) who saw classification as essential to any working infrastructure. Once the system works, it becomes ‘naturalized’. Data feminism is concerned with uses and limits of data, informed by direct experience and by intersectional feminist thought and paying attention to power and privilege.

Van der Tuin teased out the unsituatedness of classifications (Van der Tuin, 2015) in her discussion on classification’s underlying, implicit tendency to fix things. Classification is not a neutral mediator, it is “thoroughly entangled with the work that it does” (Van der Tuin, 2015, p. 19). With a focus on Harding and feminist theory as an example of classifying gesture, van der Tuin has shown the many ways in which separating feminism onto three (or any number of) distinct threads, ends up affirming epistemic categories as conflict-based. In her influential book *The Science Question in Feminism*, Harding (1986) presented a classification onto three strands: ‘feminist empiricism’, ‘feminist standpoint theory’, and ‘feminist postmodernism’. Rather than challenging positivism, van der Tuin observed how Harding’s categories stood in competition with each other, as competing feminist epistemologies. Demonstrating ‘sloppiness’ in Harding’s writing on and with Haraway’s ideas, van der Tuin concluded that such classification was unable to fully close off the categories. Taking into account Foucault’s critique of classification and taxonomy, and the emphasis he put on the situatedness of knowledge in classifications, van der Tuin but pointed out that “the situatedness of knowledge cannot be theorized or acted upon” (Van der Tuin, 2015, p. 28). She emphasized the exclusion mechanisms: "Classificatory approaches are founded on the assumption of the ability to logically list categories that mutually exclude one another." (Van der Tuin, 2015, p. 28). It is important to recognize the

impasses encountered in feminist efforts to theorize and address differentiation in the effort to situate and identify radio signals. While the discussion on Harding's classification of feminist approaches is not directly relevant to the way radio signals matter in terms of classification, the root problem of classifying gesture remains important to disclose and reject.

A useful work to consult in terms of problematizing classification in the domain of informatics and design of computational artefacts is Roberto Bottazzi's *Digital Architecture Beyond Computers* (2018). Bottazzi traced the genealogies of proof- and search-oriented combinatorics as antithetical potentialities of computation: one can either use combinatorics to prove a hypothesis, or use a generative approach to obtain an abundance of possible solutions. He recounted the case of Ramon Llull's wheels of *Ars Magna*, as a mechanism for disseminating the author's doctrine and religious beliefs. Giulio Camillo's articulation of *L'Idea del Theatro* and Leibniz's *Ars Combinatoria* are discussed as methods of search for new, unseen designs. Aby Warburg's *Mnemosyne Atlas* was a pioneering way to organize large collections by purely visual means. Contemporary design work with machine learning is a culmination of these trends for Bottazzi: a way to investigate datasets in search for patterns or sources of intuitions that can be used in architectural or urban design process, for example. Pursuing this thread further, Bottazzi made a provocative proposal for cryptography as a means to venture into domains beyond human cognition (such as abstract data, or recordings of radio signals) by carefully constructing a system of signs that move in and out of realm of human legibility (encryption and decryption) and moving productively across different domains (Bottazzi, 2019).

In search-oriented cryptographic terms, identification of radio signals would be based on the abundance of digital information, rather than on predefined instrumental categories. Such understanding of identification is inspired by Hayles' proposal for paying attention to the non-conscious information processing of machines and humans. In *Unthought*, Hayles (2017) offered a framework of looking at nonconscious cognition to speak of non-binarized approach to thinking, which is not necessarily human. She aspired to recognize the thinking of non-humans and machines. As part of this argument, Hayles stressed the role of non-conscious cognition for dealing with

abundance of information, to keep consciousness from overwhelming and the human subject from becoming psychotic. Incidentally, she described contemporary information processing technology, such as pattern recognition and visual analysis algorithms, traffic control at airports, automated trading algorithms, as examples of non-conscious cognition. Because this form of 'unthought' is a common characteristic of humans and contemporary computation, Hayles asserted, it is important to take technology into account to arrive at the definition of the posthuman. While the focus on the posthuman is not directly relevant to nomadic identities of radio signals, the notion of commonality in human and computational thinking points in the direction of articulating techniques for thinking *with* computation, augmenting the meaning already contained in the Latin term 'computare': to reckon together.

Data Observatories

Data observatories articulate a possible way to think with computation. They are part of the method and ambition to organise data on radio signals according to properties that can be defined as 'intensities' in a Deleuzian sense. This means that a perspective on any of these properties renders the dataset as a *plane of consistency* on which properties circulate as intensities. Appropriating the term used by Deleuze and Guattari in *A Thousand Plateaus* (Deleuze & Guattari, 1987) this notion emphasizes the attention to connectedness through intensities, and a capacity to compare something to something else in abstract terms that are still completely specific to that which is compared. More or less of a property can be identified in each node, each piece of data, and that they could be compared and organized accordingly. This means to articulate an archive in its own terms. I encode signals in terms of properties that are shared across the entire database. One of these properties is the probability of silence, another is the spectral entropy in the audio sample, a third is an audio identification technique called fingerprinting[5].

Data observatories give access to the knowledge of signals in their concrete manifestation: as they were received and recorded. The networks of machine learning

[5] Fingerprints are a condensed digital summary of an audio signal, based on peak points in the spectrogram which represent higher energy content. The technique is known for its use in Shazam music identification application. See (Wang, 2003).

algorithm train on each of these property sets, and produce an organized space – a grid of 'codebook vectors'[6] – that can be navigated and explored in three dimensions: according to proximity of codebook cells (horizontally and vertically) as well as according to the content of one cell (depth). Combining machine learning tools with design of *data observatories* is a way to challenge taxonomies with processes for organising unstructured data. The neural networks built with the machine learning algorithm operate in this space as mechanisms of differentiation: a way of ordering differences based on probability.

Data observatories give access to this incomplete archive in an organized way, presenting the radio enthusiast as well as researchers interested in information studies, digital humanities or media materiality, with ways to navigate the signal space according to interests and questions we might want to ask it.

Signal Identification Guide Wiki

The Signal Identification Guide (SIGID) wiki is an organized archive of information about radio signals. The SIGID wiki website is a collection of all the information about radio signals that is held among a community of radio amateurs and enthusiasts. Any radio signal that can be received and recorded can be included in the database, either as a sample of an already described radio signal or as an unknown signal yet to be identified. Each signal is characterized by signal type, frequency, bandwidth, modulation type, location, sample audio, spectrogram and a short description. The majority of signals have at least one associated audio sample, and most of the audio samples have been demodulated from raw energy recordings to audio.

The archival strategy of the community gathered around SIGID wiki is contingent on sub-group interests in radio signal application domains, such as the military, amateur radio, commercial, marine, trunked signals, or satellite reception. Signals are divided into two general categories, 'known' and 'unknown'. Unknown signals are recordings of received signals that are yet to be identified. At the time of this writing (September 2021), there are 432 known or identified and 328 non-identified signal pages on the

[6] A codebook vector is a list of numbers that have the same input and output attributes as the training data. For function of codebook vectors in self-organizing maps, see for example: (Pölzlbauer, 2004)

website. Known signals are subdivided into categories based on their application, or rather 'listening communities' – groups of people interested in tracking this particular type of radio telecommunications. All signals are also organized according to signal properties such as analogue or digital information encoding, or frequency band they occupy (very low, low, middle, high).

Transforming Data Relationships in Self-Organized Observatories

The Self-Organizing Map (SOM) machine learning algorithm is the basis for computational experiments because of its' capacity to detect patterns in unlabelled data and facilitate an explorative approach. SOM is an unsupervised machine learning technique introduced in 1980s by a Finnish computer scientist Teuvo Kohonen (Kohonen, 1982). It is known for its ability to classify data in an intuitive manner, emergent from the data. SOM has been widely used in the past forty years, across different fields such as genetics and synthetic biology, ecology but also in numerous engineering applications (Kohonen et al., 1996). More recently, a group of architects and designers explored the potentials of SOM to point at productive convergences between architecture and information technology (Bühlmann, 2013; Hovestadt, 2014). They paid special attention to informational potentiality for traversing the human/nature dichotomy, or the calculability of digital data that circulates through and even determines urban infrastructures and architecture.

Starting from an unordered collection of recordings of different transmissions and their meta-data, I organised radio signals in a rectangular grid. The grid is a way to display the data in two dimensions, by projecting the higher-dimensional onto a low-dimensional space of predetermined size, sort of a map. The relationships that emerge are observed as clusters, filtered through topologies of other data. First, values for a property of all signals – for example, probability of silence or spectral entropy – are computed using a standard feature extraction algorithm on all audio samples. These numerical values are then fed into the networks of SOM which maps alike input values closer to each other, illustrating the similarity relationships between different data items. SOM clusters data points similar to a Voronoi diagram, it arranges the means into a geographic order according to their similarity relations.

SOM brings the data points into a plane of consistency, providing measurements of similarities which circulate on it.

The data observatories provide a way to articulate signals' identities in terms of their own characteristics. I produced two different views on the signal archive, two studies that use the same techniques of differentiation: *Descriptions* and *Projections*. For each study, a web-based interface is developed, enabling navigation of the space of radio signals database according to an observer's interest. The visual language for both studies is based on the previously mentioned 'codebook vectors' grid: chunks of radio signal audio samples are distributed across the cells of the map. The first study, which I titled *Descriptions*, explores radio signal data alone, while the second study, *Projections*, explores projections of the radio signal data on an external dataset which is closer to human experience, such as music, bird songs, urban sounds. I will present here two vignettes on the use of data observatories, and then discuss their implications for articulating nomadic identities of radio signals across the data observatories.

Descriptions

Descriptions are a projection of audio sample data onto textual descriptions of radio signals written by contributors to the SIGID archive. This process establishes a connection between the inaccessible domain of electromagnetic radiations (radio signals) and the accessible domain of language. Radio signals are intended for machine-machine communication and only translated into information upon reception. I work with recordings of radio transmissions, without examining their content. The organisation of this non-intuitive, inaccessible data has to be approached through a different domain, which, in this case is the adjacent domain of textual descriptions, associated with each signal in the database. I used a topic modelling algorithm[7] on these descriptions, to generate lists of the most important. There are words that speak of military use and international relations (spying and jamming); there are technical words that speak of protocols and demodulation; there are groups

[7] I worked with Latent Dirichlet Allocation (LDA) as topic modelling algorithm. LDA is a form of unsupervised learning that processes text as 'bags of words' looking for statistical correlations. Topic modelling or topic detection is a machine learning method to discover human-readable topics in text.

of words that are associated with radio amateurs. Starting from one of the identifies ‘topics’, the archive unfolds in directions of individual interests, tracing similarities across sometimes completely unrelated signals.

Figure 1. ‘Data Observatory: Descriptions’ web interface. Red cell in the middle contains a part of the HAARP signal, which resembles ‘neon lights’ (right pane) discussed in Vignette 1. Visit the web-interface online at https://radioexplorations.ch/descriptions/ (accessed on 17.02.22)

Figure 2. ‘Data Observatory: Descriptions’ web interface. Zooming in on the nine ‘topics’ represented here by lists of keywords separated in blocks.

Vignette 1: How to approach an archive without knowing what you are looking for? I take any signal and look at it, for example ‘High frequency active auroral

research programme' (see Figure 1) whose samples appear in the center of the map. The signals' spectrogram looks like a photograph of neon lamps in space. But this is not a photograph. It is a time-frequency representation of sound. Its description says it belongs to a research programme studying the properties and behaviour of the Earth's ionosphere. Reading about ionospherics elsewhere, I learned that some climate research uses data on lightnings to measure the degree of climate change. They found, already in 1999, a significant correlation between the increase in temperature and in lightning activity in the northern hemisphere of our planet.

This is a short observation that can emerge from descriptions of radio signal transmissions. One prominent topic that emerged from topic modelling is relationship between the military and telecommunications (see Figure 3). Is there something new and specific we can learn from this setup? The second vignette suggests some possible stories about this connection.

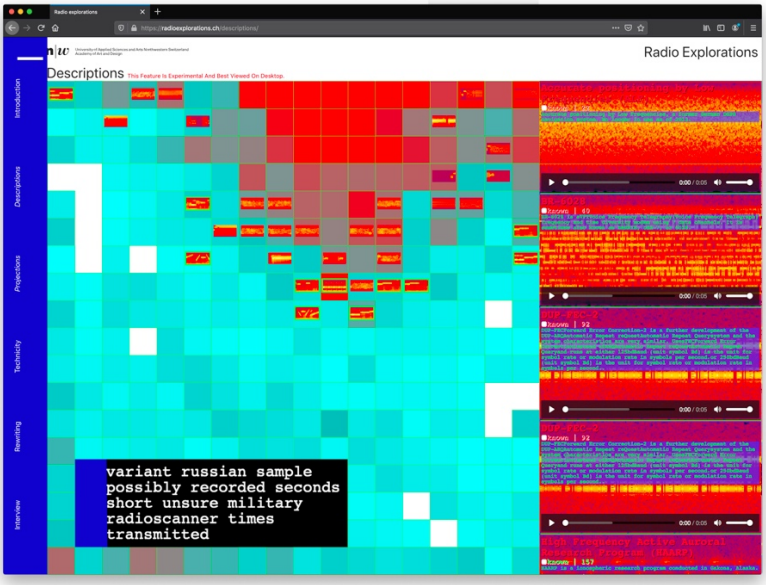

Figure 03. 'Data Observatory: Descriptions'. Highlighted topic (overlay, bottom left) corresponds to the non-empty cells. Among them, highlighted is the HAARP signal.

Vignette 2: I highlight one topic that speaks about military and some related keywords. Interestingly, the signal from previous story is found in one of the cells at the bottom of this area. It is a rhythmical sample that has a similar rhythm and spectral power to DUP-FEC-2. I notice the FEC in the names of other signals.

> *Apparently, FEC stands for "Forward error correction" – an error control method used in situations where retransmissions are impossible. What this cell tells us about military: it is tightly connected with diplomacy and intelligence; impossibility of retransmission is characteristic of military communication.*

To notice the connection between military and intelligence requires little more than common sense. Yet here we have some form of proof, a tangible connection between telecommunication practices and citizen knowledge, engineering and politics, established through the cognitive assemblage of this computational artefact and an active, interested explorer who poses questions. Even more importantly, the example hints at a way to articulate what we know about one signal. The SIGID wiki archive's purpose is to support identification of radio signals found 'in the wild'. Here we encounter a way to approach the identity of a signal as nomadic, to establish a nomadic identity for any signal in the database. Parts of a signal's samples can be found on many different cells (see Figure 3, green highlighted cells of the HAARP signal for example). A signal shares some properties with other signals in the cells it occupies. It zigzags across similarities in the properties that articulate a 'data observatory'. These properties describe qualities of that signal, and at the same time, propose new categories or clusters by which signals could be organized. Nomadic identity is not a subject, but it is open to intense flows of interest and information.

Projections

The second data observatory *Projections* enables the comparison of radio signals by articulating their similarity in terms of an external dataset that illustrates different genres of music. In this data observatory, radio signals are organized through musical genres in the following way: the SOM algorithm does not compare radio to music, but projects radio signals onto a previously computed model that organised songs from the Free Music Archive (FMA) dataset for music analysis[8] and its eight genres (see Figure 4). A pragmatic question to ask is whether this organization can support identification of 'unknown' signals? This would mean to match a signal categorized as

[8] See more about the dataset and access the files archive: https://github.com/mdeff/fma (accessed on 17.02.22).

'unknown' to a 'known' signal from the database. In radio amateur practice, this is done by careful observation of different signal properties by someone who has already 'seen' and 'heard' a large number of signals, and understands patterns left by different communication protocols. I propose to work differently: to find a plane of similarity, in comparison to which I can establish similarities between signals in projections and reflections off of a different kind of data. Now, it becomes relevant how radio signals samples are placed next to each other: a direct similarity between radio signals on the map should reflect their likeness in an aspect that is shared with audible information on music.

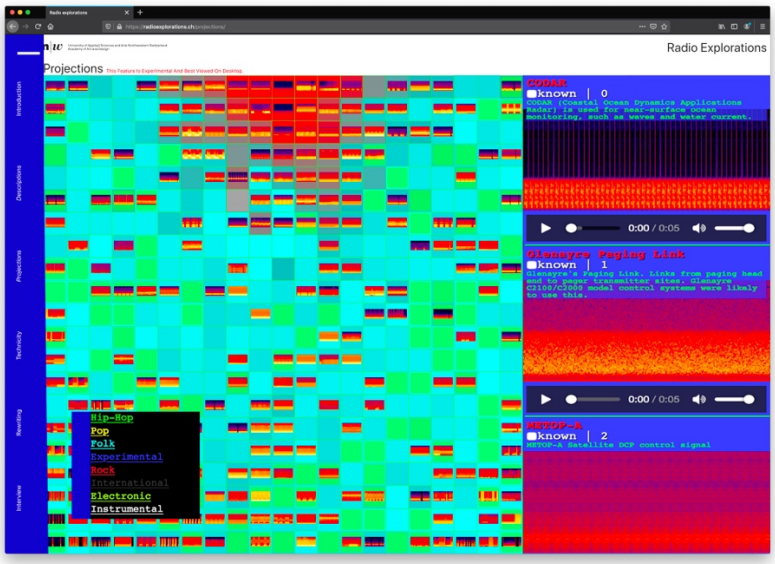

Figure 4. 'Data Observatory: Projections': Signals are 'projected' onto a pre-organized map of musical samples, labelled according to the genre (overlay, bottom left). Each genre 'highlights' some cells among which certain radio signals can be found. Highlighted here is the 'Hip-Hop' genre. Visit the web-interface online https://radioexplorations.ch/projections/ (accessed on 17.02.22).

Together with the administrator of the SIGID website, we identified some interesting groupings of unknown signals. We found out that a lot of the 'similarity' between songs and radio signals comes in as an artefact of recording, listening itself, the fact that these are transmissions in the environment, modulated by the spatial conditions, and equipment operation. This points to the importance of not taking the results of algorithmic processes on data as 'truth about the world'. Data can be very noisy, or is speaking of a different phenomenon altogether. Therefore, it is only interesting to use

these algorithms in order to gain multiple perspectives on the data, to articulate careful and specific questions, and then consider doing something about it.

Machine Reason

The articulation of nomadic identities of radio signals discussed in this article demonstrates and problematises the capacity of machine learning techniques to support reasoning about environmental radio transmissions. The digital, argued David M. Berry (2012) in his introduction to *Understanding Digital Humanities*, is the new unifying idea in academia and knowledge. With this new idea, reasoning shifts towards a more conceptual or communicative method, a way of thinking that raises different kinds of questions (e.g., how many times a word repeats in a text) and leads to different kinds of findings. We can observe in the vignettes (*Descriptions* and *Projections*) described above, how machine learning algorithms challenge the way we ask questions: it is not so much about finding correlations – they are abundant; but about constructing meaningful ways to interpret them.

Neural networks extract whatever we decide is the essential information from the data, but they do not give us 'reason' for it. For example, when the proximity of nodes in a recommendation algorithm is interpreted as a prediction that one should buy items whose vectors are closely linked, neural networks are mobilised to provide reason for purchase, or a suggestion of it. I do not want to imply that such recommendation systems do not work well – because they do. Such direct deductions tend to only confirm what we already know. With the exploration of radio signals, on the other hand, I strive to demonstrate the capacity of machine learning processes to articulate nomadic identities of radio signals always anew, always different depending on the perspective. Reasoning with machine learning algorithms therefore is only appropriate if it does not lead to interpretations of the world, but if we take its outputs as an incentive to make another translation, to go to a new place.

Working with machine learning algorithms as a way to articulate identities of radio signals opens up a space of different thinking which is characterized by synthesis instead of analysis. Computers bring together concerns of mathematics and matter, ideal and material. Notions such as synthesis, entanglement and assemblage enable

to round out the simplification and abstraction of clean materiality, and embrace continuity in a fleshy, touching, incorporating, and ever-changing sense. New materialist alertness to fixed, predetermined modes of existence is expressed in a related way by Coole and Frost (Coole & Frost, 2010) who challenged the common sense that "real" material world consists of solid, bounded objects with predictable and controllable behaviour. They critiqued the notion of matter as "identifiably discrete" and trace a number of ways this has been problematised by chaos and complexity theory, quantum physics, genetics biology, and biopolitics. In the most general sense, this alertness is addressed at unsettling the human/nature dichotomy, to which radio signals lend themselves well, in the sense that they can exist as natural and human-made phenomena.

This article proposes to consider characterizing things through synthetic differentiation, and through the lens of a carefully considered question. It affirms articulation of differentiating algorithms that preserve flexibility in terms of parameters and enable observations that do not issue from established ontological categories.

Conclusion

Radio signals are hard to categorize and characterize because we have no direct experience of them, but encounter them through technological translations and transformations. By unpacking radio signal identification process as it is conventionally practiced by radio enthusiasts, in this article I discussed ways to establish an organized radio signal space prior to categorization. This de-territorializes, or rather re-territorializes radio signal identity in terms of other radio signals, and avoids looking at signals based on what they 'do' (anthropocentric view) and how they exist technically (a form of essentialism). Our techno-life world could benefit from new ways of reading radio, and for that matter, other telecommunication infrastructures and computational technologies. Katherine Hayles suggested thinking about these as cognitive assemblages: more or less loose connections of humans and technical devices through which cognitions, interpretations and meanings circulate (Hayles, 2017). This would mean to recognize the entanglements in

functioning of, for example, the airport traffic control and check-in area, prominently described in Rob Kitchin and Martin Dodge's book *Code/Space* (Kitchin & Dodge, 2011). Liveable worlds depend on our capacity to notice and consider entanglements with technology and for that, we have to concentrate on developing tools to gain multiple perspectives on data.

Several ideas for novel ways of reading datasets and archives, in circulation among new materialist and science and technology scholars, are relevant to this argument. Tahani Nadim drew on Arondekar's urge to find "new ways of both mining and undermining the evidence of the archive." (Nadim, 2021). She suggested "encountering the archival trace as a 'recalcitrant event,' a notion borrowed from Shahid Amin that abandons the impetus of 'discovery' in favour of mobilizing traces in and through narration and interpretation." (Nadim, 2021, p. 129). Every archive, database, and archival practice instils a specific set of beliefs and hopes in advancing accuracy and capacity to reason with it.

In a media-archaeological exploration of wireless networks (radio waves) in space, Miyazaki and Howse proposed transduction devices to make sense of network connections by rendering their electromagnetic emissions sonically accessible (Miyazaki, 2013). Sonification of networks acts as an epistemic experimental system which discloses the ongoing algorithmic processes within urban areas. Sound enables one to 'make sense' of electromagnetic activities. I propose a related approach to radio signal archive, to develop a sense of data that is intuitive like sound. The approach discussed in this article enables us to make sense of digital information about radio signals on a level that is different from modernist objectivity, and yet is not purely subjective: we are able to discuss and share experiences of working with data observatories.

The outputs of this project aim to facilitate speculation on the connection between signal representation and technical communication protocols, by shifting criteria of similarity from taxonomical and instrumental (i.e. used in military) or physical (i.e. high or low frequency), to properties shared across all signals – such as the probability of silence or noise in the signal. Neural networks of the SOM algorithm extract whatever we consider as essential information from the data on radio signals. Working with SOM as instrument, enables us to observe affinities and interests as the main driver

of these explorations. Data observatories built with SOM as instrument are computational artefacts that provide measurements of similarity between data points, and enable a multiplicity of perspectives on the data.

The dataset I work with, created from the SIGID wiki entries, is something more than a discrete database. It testifies of a knowledge community that forms around the question of technical literacy of telecommunications. One of the collateral outputs of this work is the use of digital observatories as tools to assist the identification process for signals that are currently categorized as unknown.

While machine learning is often discussed in humanities in terms of its biases and problems with optimization, this article stresses the importance of digital literacy when working with digital information. I articulate how identities can be read in machine learning statistical models. It is an experimental method of working with biases, in order to make them legible, countable and accountable. I propose these identification processes as arbitrary, nomadic renderings of reality in the eyes of a machine, affirming inherent instability and flexibility of a signal's identity. By rendering signals commensurable in this way, I propose to take an active stance with regards to machine learning algorithms and expose a research interest from which we can learn and tell stories about signals.

Acknowledgements

The Radio explorations research project was generously supported by the SNF-Spark funding grant number 190310. I am grateful to my collaborator, Yann Patrick Martins for programming the data observatories, and to our research workshops guests: Carl Colena (SIGID wiki), Miro Roman (ETHZ), Simone Conforti (IRCAM), Sarah Grant (Kunsthochschule Kassel) and Roberto Bottazzi (The Bartlett) for their invaluable inputs. Special gratitude goes to Miro Roman for numerous informative discussion on working with SOM and big data, as well as to Carl Colena for his support and discussions on radio signals beyond workshops and interviews.

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Discerning Relational Data in Breath Patterns. Gilbert Simondon's Philosophy in the Context of Sequence Transduction

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DOI: https://doi.org/10.1344/jnmr.v3i1.38961

Abstract

This article discusses Gilbert Simondon's philosophies of the technical object, information, and individuation to frame the potential inherent in a practical application of his notions of *intensity*, *amplification,* and *transduction* of relational processes, which have been largely neglected in the traditions of substantialist and hylomorphic thought. Specifically, the study introduces a method to discern relational information by amplifying audible breath patterns of a collective via a wearable digital stethoscope (WDS). The non-lexical modality of the breath grants insights into non-verbal phases of communication during which multiple points of view may exist simultaneously. These points of view can be understood as a subject's sense of orientation within phases prior to signification, i.e., before *affect* becomes a specific *emotion* and before *perception* becomes a concrete *action*—using the terms as they are defined by Simondon. Bodily movement is audible within the breath and can be further transcribed into preliminary signs with the help of a sequence transduction machine learning (ML) model. Discerning semiosis within audible breath patterns exemplifies a logic of computation which is not concerned with quantitative and qualitative information but, instead, computes intense data to grasp relational dynamics.

Keywords

Intensity; Breath patterns; Sequence transduction; Digital wearable stethoscope; Transindividual, Gilbert Simondon.

Introduction

> "[T]he technical object is the form, the material crystallization of an operational schema and of a thought that has resolved a problem. In order for this form to be understood it is necessary that there be analogous forms in the subject: information is not an absolute advent, but the signification resulting from a relation of forms, one extrinsic and the other intrinsic with respect to the subject." (Simondon, 2017, 253)

Technical objects are relational objects. In inter-human relations they create *transindividual* relations which French philosopher Gilbert Simondon describes as created by the invention of the technical object as an intermediary (Simondon, 2017, 253). He further describes transindividuality as a process which creates information not yet matter or form but the transition or in his words, the *transduction* which constitutes processes (Rodriguez and Blanco, 2016, 42). This study utilizes Simondon's theory of information both hermeneutically as well as operationally by outlining tactics to discern relational information in audible breathing with the help of wearable digital stethoscopes (WDS) and a machine learning (ML) model. Simondon's theory provides the language to describe how the audible breath contains relational and *intense* information that is organized neither by Gestalt theory's structural qualities or "good form," nor by information theory's "quantity of pure information" (Simondon 2021, 267). Intensity of information, as described by Simondon, is, instead, organized around a context unique to each subject due to the degree of relatable information within a specific situation (271).

Intensity of information is, thus, a singular modality and perceiving as well as analyzing it calls for a methodology which retains singularities and context without classifying them into categories. This article adopts Simondon's vocabulary to establish a new materialist methodology as an operational alternative to common dualist mechanics of computation. It reimagines the purpose of datasets in general and reorients artificially intelligent agents towards the analysis of intense and unannotated data. In order to capture intense uncategorized data, the study first lays out how the breath is identified as a modality which expresses the intensity and relationality of living organisms. It then discusses how the WDS traces these intense

relations by capturing the breath and rendering the ephemeral modality of intensity a subject of further analysis. Finally, the study outlines a sequence transduction ML model capable of analyzing this transindividual data within the breath. This ML model computes transindividual data as it is described by Simondon's theories of the technical object, information, and individuation. This mode of computation allows one to a) discern patterns of relation in real time and, thus, predict future movements and b) reflect on these patterns of captured intensity by tracing the semiosis indicated by their recurrence. Due to its ability to train on singular and constantly evolving data, this model is not deployed to find preconceived categories but rather to detect recurring patterns, in other words, semiotic elements that evolve within the joint breathing of a particular dyad. Targeting the breath as transindividual data takes into consideration the constant influence the environment has on subjects as they are individuating. These changes within the data are frequently ignored by the logic of classificatory algorithms.

Breath as a Singular and Multi-perspectival Modality

In a Simondonian reading of the term *intensity* (2021, 267), a subject's subtle physical reactions to its environment contain intense information that cannot be quantified but only perceived in its idiosyncratic context. The audible breath is tightly linked to the body's reactions and its kinaesthetic awareness. It is susceptible to nuances of the body's expressions since muscles move with regards to the oxygen they receive. Prelexical, expressive, but rarely concerned with signification, breathing functions as an *intentional cue* (Corness, 2013, iv). It informs what cultural theorist Erin Manning has termed *preaccelerations,* or the process and virtual force of bodily movement taking form (Manning, 2009, 6). In other words, discerning patterns of breathing reveals how a body is about to move, and discerning breath patterns of bodies in relation to one another reveals information about how they are moved by each other.

Interactions are commonly described as occurring between individuals defined through either a substantialist or hylomorphic viewpoint. These conceive living beings either as part of a unity or as an amalgamation of form and matter (Crary and Kwinter, 1992, 297). Simondon counters both monism and bipolarity by focusing on an

ontogenesis which accounts for the fact that living organisms are constantly *individuating*, i.e., developing, growing, aging, decaying, and only able to do so by being entwined with their environment, or their *milieu* (Simondon, 2021, 7). He argues that this active genesis is not accounted for in monism or pluralism, which equally rely on an already individuated substance and "put themselves in the impossible situation of rediscovering an effective genesis" (304).

As a result of the effective genesis in his theory of individuation, Simondon describes perception and communication as processes which are neither fully quantifiable nor fully qualifiable. He, instead, turns to the notion of intensity which renders perception a process that does not have a finite number of solutions but retains room for multiple solutions simultaneously (271). These simultaneous possible solutions are constantly present when organisms' encounters are "grasped as transductive and not as classificatory" (Simondon, 2021, 359). Transductive encounters cannot be measured or secured by qualitative or quantitative means; they are contextualized through their *intensity of information* (269). Graspable neither as quality nor as quantity, intensity is a slippery feature to analyze. To track intensity, one needs a modality which traces, however, does not signify and repress intensity by merely rendering it into yet another quality or quantity.

In this study, the focus lies on the non-lexical intensity of breathing, which reflects the movements performed by bodies. The modality of the breath traces their encounters in a non-intrusive manner as it remains non-lexical even when captured with the WDS. The non-verbal expressions of bodies, evident in their breaths, provide a record of the reciprocal and simultaneous exchange which takes place constantly amongst bodies and their environment. This form of casual nonverbal communication is not organized around questions and answers, or more generally, around the notion of turn taking as dictated by the structure of verbal communication. Instead, organisms exchange intense nonverbal information at a fast pace and make and adjust their propositions simultaneously and constantly (Barsalou, 2003; Barrett, 2017; Bateson, 1977). A verbal proposition to cooperate with another is, for instance, spoken by a body, which cannot help but produce nuanced and constantly adjusting expressions.

Whenever these adjustments are mutually recognized and acted on, this formation of movement potentially actualizes joint gestures. In this case, the idea or movement can no longer be traced back to one source and necessarily contains more than one perspective. This happens frequently during, for example, the enactment of both scored and improvised dance and music (Foster, 2019; Manning, 2007; Sawyer, 2003), as well as in everyday encounters. The multiplicity of perspectives negotiated non-verbally are neither finite nor categorized and thus remain receptive to continuous adjustments. Cultural theorist Erin Manning calls this "movement's capacity for invention" (2009, 19) and explains that subjects can experience a symbiosis when they perceive each other as both active and passive and are no longer aware whether they are following or initiating their shared impulses (Manning, 2007, 101). In this context, the mechanics behind the process of symbiotic individuation are applied to computation and function as an alternative to the common comparative model. Simondon's framing of intensities provides the language to describe the breath as a multi-perspectival modality that can trace this symbiotic individuation because it is a necessarily relational feature–at once impression and expression–and amounts to an operation which does not settle on one particular meaning or form.

Intensity

Gilbert Simondon (1924-1989), Philosophies of Difference, and New Materialism

Simondon worked towards bridging engineering and science through philosophy while focusing on operations rather than on structures and on relations rather than on identities (Rodriguez and Blanco, 2016, 34). The notion of intensity is central to his theory of information, his theory of the technical object, and theory of individuation. He applies intensity to bypass qualitative and quantitative signification in order to access and discuss the ephemeral.

A student of phenomenologist Maurice Merleau-Ponty, Simondon is considered a precursor to poststructuralism, specifically to philosophies of difference and new materialism. He had great influence on philosopher Gilles Deleuze and his

elaborations on difference as intensity's form, on virtuality, and on his refusal to rely on a binary logic of negation (Deleuze, 2001, 52). Australian philosopher Elizabeth Grosz (2019) contextualizes Simondon's influence on Deleuze, herself, and feminist new materialism more generally, by pointing out that it is in part Simondon's theory which provided the language for Deleuze's ethics of the event (171). She writes: "[i]nstead of opposition, Simondon speaks of disparation, the productive tension between two closely related but incompatible orders; instead of identity, or individuality, he speaks of individuations; instead of forces, he speaks of energetic potentials; and instead of the negative, he speaks of creation" (171). This language, to her, suggests an ethics around the study of ontogenesis instead of an ontology (170); it creates a wide and further dispersed notion of agency that is experienced through the entangled becoming of subject and milieu. Grosz concretizes the cultural relevance of Simondon's abandonment of hylomorphism by arguing that his ethics displaces the hylomorphic model and along with it dichotomies established since Aristotle if not earlier, such as, on the one hand, matter connoted as being passive and feminine, and on the other hand, form connoted as being active and masculine (171). Philosopher and political theorist Jane Bennet (2010) similarly points to the neglect of the androcentric and discriminatory hylomorphic model by both Simondon and Deleuze via their notions of intensity. She elaborates on Deleuze and Felix Guattari's notion of material vitalism, which, counter to the hylomorphic model, regards matter as lively in itself. Bennett traces Deleuze and Guattari's notions of "intensity," "virtuality," "matter-energy," or "pure potential" that counter the notion of hylomorphism back to Simondon's prior, however, publicly less recognized efforts in achieving exactly this via the concept of intensity (55, 56). Feminist new materialism has brought forward a considerable amount of research which rests upon and discusses Simondon's concepts of individuation and information and his critique of dualist thought, for instance, his critique of Norbert Wiener's concept of information as analyzed by Andrea Bardin (2021, 9), or Émilie Filion-Donato's (2021) recontextualization of the notion of individuation, power, and curiosity within the context of psychoanalysis and materialism, via the work of Ernst Schachtel, Karen Barad, Donna Haraway, and Evelyn Fox Keller. Simondon's reach beyond the dichotomy of form and matter has created an ethics and vocabulary which remains

operational and concrete despite his discussion of the ephemeral notions of intensity, relationality, and communication.

Incisiveness of Perception

In order to describe the ephemeral dimensions of communication which can be revealed through the breath, it is necessary to adopt a language which accounts for a dimension that cannot be described by referring to qualitative or quantitative measures. In his effort to frame information, Simondon introduces the notion of *thresholds of intensity* as points of reference and as an alternative to the references of quality and quantity (2021, 264). He uses the example of a photograph to explain that in order to define the reality of information neither information theory nor Gestalt theory provide adequate solutions. While information theory defines information via the quantity of available units by which information can be stored and represented, i.e., a coarse or fine emulsion of a photograph (265), Gestalt theory argues that "good form", in other words, an image rich in information, is discerned by structural quality. This structural quality, however, amounts to the number of signals required to transmit a degree of complication and does not offer a logic different from that of quantification (267). Neither of these approaches accounts for the relational dimension of perception in the sense that humans do not perceive objects as individual by grasping an "inexhaustible reality, like matter" but, instead, by perceiving "the reality of certain thresholds of intensity and of quality maintained by objects" (264). When increasing the contrast of a photograph, for instance, objects might be perceived as clearer while information theory would claim that information is lost. Similarly, in the context of this study, information is "lost" while rendering the WDS recordings more *intense* by considering only the frequencies within the range of 100-1000 Hertz (Hz). This selection foregrounds the breath sounds and renders them more expressive by eliminating background noise, such as heartbeats, in the range below 100 Hz, as illustrated in Figure 1.

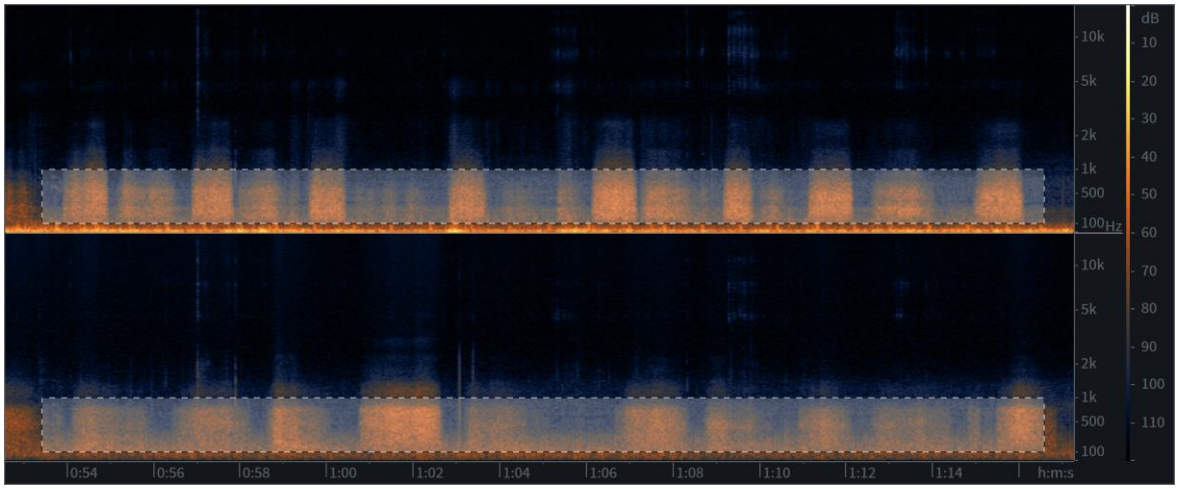

Fig. 1. Simultaneous WDS recordings of the breaths of two subjects. The selection of frequencies between 100 and 1000 Hz foregrounds the breath's *expressivity*. An audio sample can be found here: https://vimeo.com/672922743 (accessed on 17.02.2022)

Simondon explains that a subject's perception is dependent on this notion of expressivity (267). An image might thus be expressive and hold information due to the fact that it is slightly out of focus or that it has a shallow depth of field. "A geometrical rigor of a contour," on the other hand, might carry less information and amount to a less incisive[1] perception (268) because the content is less unique to each subject due to the lesser degree of relatable information within a specific situation (271). He explains:

> "Certain tonalities, certain colors, and certain timbres can be part of an intense perception without even constituting a good form. It thus seems necessary to distinguish between the clarity and the [incisiveness][2] of a perception; [incisiveness][3] is veritably linked to the dynamic nature of the perceptive field; it is not just a consequence of the form alone, but also and more importantly a consequence of the range of the solution it constitutes for the vital problematic." (271)

[1] In the only translation of Simondon's *Individuation in Light of Notions of Form and Information* to date, the French word *prégnante* was translated with the English term pregnant. In French, the word *prégnance* translates to *incisiveness*, which, despite of its etymology (Latin *praegnans*), is not used to describe the biological state of a pregnancy or being pregnant. In French it is not the word *prégnante* that describes a pregnant body, instead the word *enceinte* is used. What in the English translation might seem like problematic neutral use of language by the author, is instead an inaccuracy in the translation by Taylor Adkins. For this reason, I will exchange the translated terms "pregnancy" and "pregnant" with the term "incisiveness" and "incisive" in this article.
[2] My annotation, see footnote one.
[3] My annotation, see footnote one.

The vital problematic describes the residual nature of life for the individuating subject that due to its constant development cannot take on signification and constantly remains exposed to a multitude of solutions to the problem of life (237). Intensity, or the incisiveness of perception, thus remains ephemeral and may be "confused" rather than clear and "will be more [incisive][4] in proportion to how dynamic the prior state of incompatibility is" (271). Simondon gives the examples of intense desire, fear, or the perception of a smell which may each be intense, however, are often perceived as rather unclear or confused as they do "not include solidly structured elements" (271). Nonetheless, intensity functions as a means of orientation by adhering to objects as temporal stabilizations of a milieu in flux (270).

Incisiveness of Concepts and the Breath

Equally in flux, breathing can be described as a metastable modality which traces situations through its perpetual fluctuation and adaptation. This study charts breath as a modality which is situated in the center between perception and signification. When Simondon notes that the "genesis" of concepts results from a process of "ongoing reactivation" similar to that of forming perceptive units, he remarks that there is no clear separation between that which is perceived and the perceiver, but rather, an "inter-perceptive" tension which relates the subject to the world and to itself. The temporal dimension, too, is not divisible into that which was there before and that which is happening while a subject perceives its environment. Instead, Simondon describes a metastable situation in which "a priori forms do not rigorously preexist perceptions" (271).

Concepts, mediations, and information are thus discovered from the center between a metastable form and an equally metastable perception as neither of these terms preexist one another. The pre-lexical while informative nature of breathing is situated in this center of intense mediation because it traces the dynamic tension of the subject and its milieu while the breathing subject is in the process of perceiving. Breath is tracing the simultaneous transductions of perception towards signification

[4] My annotation, see footnote one.

and signification towards perception. This process is necessarily relational and a constructive potential innate to the individuating subject and its environment, in other words, "relation does not spring forth between two terms that would already be individuals; relation is an aspect of the internal resonance of a system of individuation; it belongs to a system state" (8). Investigating the audible breath as an internal resonance of a system operates both hic et nunc and at the level of concepts when considering the WDS recordings as traces of semiosis. The WDS enables this tracing of specifically the auditory qualities of the breath with their perceptual attributes such as timbre, i.e., auditory brightness, roughness, attack quality, and inharmonicity (Siedenburg et al., 2019, 24). These are characteristics which contribute to the incisiveness of perception due to the degree of intensity they invoke. Intensity of information, such as timbre is a means by which subjects orient themselves within vital dynamism and, in the words of Simondon, "[e]very received signal in this sense possesses a possible coefficient of intensity due to which we constantly correct our situation relative to the world we inhabit" (269). To summarize, there is intensity in any perceived signal and intensity contributes to the incisiveness of perception while it is not necessarily a clear signal. Clear signals, such as concepts and information, arise from an interpretative and necessarily relational tension. This relational tension is pre-individual, and it contributes to the internal resonance of a system. Within a subject there are aspects of this internal resonance that can be discerned by tracing its audible breathing.

In order to trace a subject's breathing a technical object needs to transform the sound of the breath into electrical energy. As a technical object traditionally used for auscultation a stethoscope renders internal sounds of the body more perceptible to the human ear. The membrane functions as a resonator which, when placed against the skin, amplifies sounds coming from inside of the body. My WDS consists of a lavalier microphone which is attached to a stethoscope head via a short piece of stethoscope tubing; it allows to record clear breathing sounds, and specifically sounds of the breath of bodies in motion. It provides a more feasible and lag-less alternative

to current models on the market,[5] and it can be constructed from off-the-shelf components. The signals presented in this study have been recorded at the throat while the stethoscope head was secured around the neck with a strap. Because of the relatively small diameter of the neck, a stethoscope head with a small diameter (infant size) creates a clearer signal as the membrane's surface touches the skin more evenly. The images below show the assembled WDS (Fig. 2).

Fig. 2. WDS comprised of a stethoscope head and a short piece of stethoscope tubing which connects the stethoscope head and a lavalier microphone inserted at either side of the tube. 3.5mm TRS audio jack connection (right); lightning connector (left).

Transindividual Breath

> "The technical object taken according to its essence, which is to say the technical object insofar as it has been invented, thought and willed, and taken up [*assume*] by a human subject, becomes the medium [*le support*] and symbol of this relationship, which we would like to name *transindividual*. … An inter-human relation that is the model of *transindividuality* is thus created through the intermediary of the technical object" (Simondon, 2017, 252-253)

[5] This WDS is reliable and more feasible (≈$30.00) than the two devices currently on the market: *Thinklabs One digital stethoscope* ($499.00, professional medical equipment), and the *Stemoscope* ($79.99), which lags due to its bluetooth connection.

The Collective

The transindividual relationship relies not only on the invention of the technical object at its center but Simondon furthermore specifies that the "weight [*charge*] of pre-individual reality" with its "virtualities and potentials" (253) is part of this connection. The *pre-individual* is tied to the perpetually changing formations within the process of individuation; it describes not a fixed individual but, instead, the subject, which is defined by Simondon as in constant development and both pre-individual and individuating (Simondon, 2021, 348). The notions of the pre-individual and individuation account for relationships which render situations metastable and "turn them into problems with multiple solutions" (262). These solutions can only be accessed through the collective as the only way for the subject to coincide with both its pre-individual and individuated facets, thus with itself, is through the collective as a reference.

Simondon explains the necessary reciprocity of the collective and the subject by defining emotion as the signification of affectivity while affectivity is the foundation of emotion, and action as the signification of perception while perception is the foundation of action (279). Both affectivity and perception bring to the subject "something from the outside" (280) through the other by means of the individuation of the collective, which constitutes the environment. An exchange between subjects is necessary in order to concretize perception and affectivity towards potential solutions pursued via action and felt as emotional "states" and for the subject to become aware of affect and perception. This notion of awareness of affect and perception, however, cannot be fixed within a semantic or even semiotic solution. At that point, it could be described as an emotion or an action, and it would no longer be intense. Breathing is one of the few activities that simultaneously engages the subject consciously and subconsciously. Due to its non-lexical disposition and consistent fluctuation, the action of breathing is an activity present throughout the formation of affect, as well as emotion, and throughout perceiving, as well as acting. A focus on the subject's metastable exchange of gases with the environment and the collective, indeed, further blurs these boundaries. The notion of the subject is porous. By tracing the tangible im- and expressions of a collective via their breaths, the intangibles of

affect and perception become, to some extent, traceable. Tracing commonly applies to quantitative and qualitative representation and not to intense processes. Here, the intensity of affect and perception can be recorded within the non-lexical modality of the breath while emotion and action equally leave traces within the breath and–more concretely–within language. The Canadian philosopher Brian Massumi (1995) specifies this connection between language and emotion; he calls an emotion a "socio-linguistic fixing" (85), a personal and qualified intensity which is *de facto* no longer in flux, affective, or intense. As mentioned earlier, the modality of the breath escapes the common mechanics of verbal turn-taking or, in Massumi's words, the "narrativizable action-reaction circuits" (85) of a semantic order. He speaks of a paradoxical suspension of affect and intensity which exists simultaneously in flux and as fixed states and solutions while he defines emotions as concrete units which lack intensity due to their semantic qualities (86). Within the breath patterns which emerge in a collective, the paradoxically active while simultaneously passive potential of intensity and affect is retained.

Affect and perception are active only in this intense state of suspension wherein subjects collectively render some aspects of this suspension emotion and action. It is energetically potent because it is a collaborative moment during which more than one perspective is in the process of forming. Simondon (2021) parallels this process to that of solving a problem when he writes: "the position of the problem in a certain sense bears the possible solution as a tension toward a signification that incorporates the data of the problem, albeit without the prior formation of the effective lines of the solution, which would only appear through the real becoming of resolutive invention" (367). Resolutions are moments which shed the potential of the multiplicity from which they are derived. They are simplistic enough to function well within the teleological order which tends to dominate encounters on the surface. Working with pre-individual affective states takes a paradigmatic shift which designates resolutions as partially counterproductive and, instead, sets the focus on relations.

Breathing as Relational Amplification

Organizing knowledge according to the simultaneity inherent to a relational logic and foreign to a logic of resolutions can be traced within breathing. Breathing traces and thus reveals the process during which perception and affectivity are enacted as a way of knowing before they are transduced into concrete states, i.e., before affectivity becomes a specific emotion and before perception becomes a specific action. A multiplicity of possible solutions, in other words, relational knowledge, is thus retained as long as the particular situation is not yet signified but nevertheless *real*. Relational processes constitute the *real* in Simondon's theory of individuation. Reality is not behaving according to substances which define certain terms, instead, substances are temporal states in motion as the relations they are composed of are constantly forming anew (5). Relations are furthermore an epistemological reality or a "*constitutive, energetic and structural condition"* (76) which is not dependent on form or matter.

In contrast to teleological thinking, this form of relational knowledge enacts multiple real points of view simultaneously. Equally in a state other than that of a clear signification, the audible breath of a collective reveals a multiplicity of solutions within a situation because it is directly involved in any movement the bodies do or do not make. These movements can be traced through the breath and via the WDS. Accessing this collective way of knowing with the WDS and further discerning patterns in the breathing of multiple subjects with a sequence transduction ML model, as described in the following sections, is analyzing a form of *amplification* (396), which Simondon defines as an act which does not have a resolutive limit and thus has the capacity to go beyond itself (378) and beyond one particular point of view. This amplification with its simultaneous viewpoints is depicted in the following spectrograms which show WDS recordings of the breaths of a dyad involved in a number of different activities (Fig. 3-7).

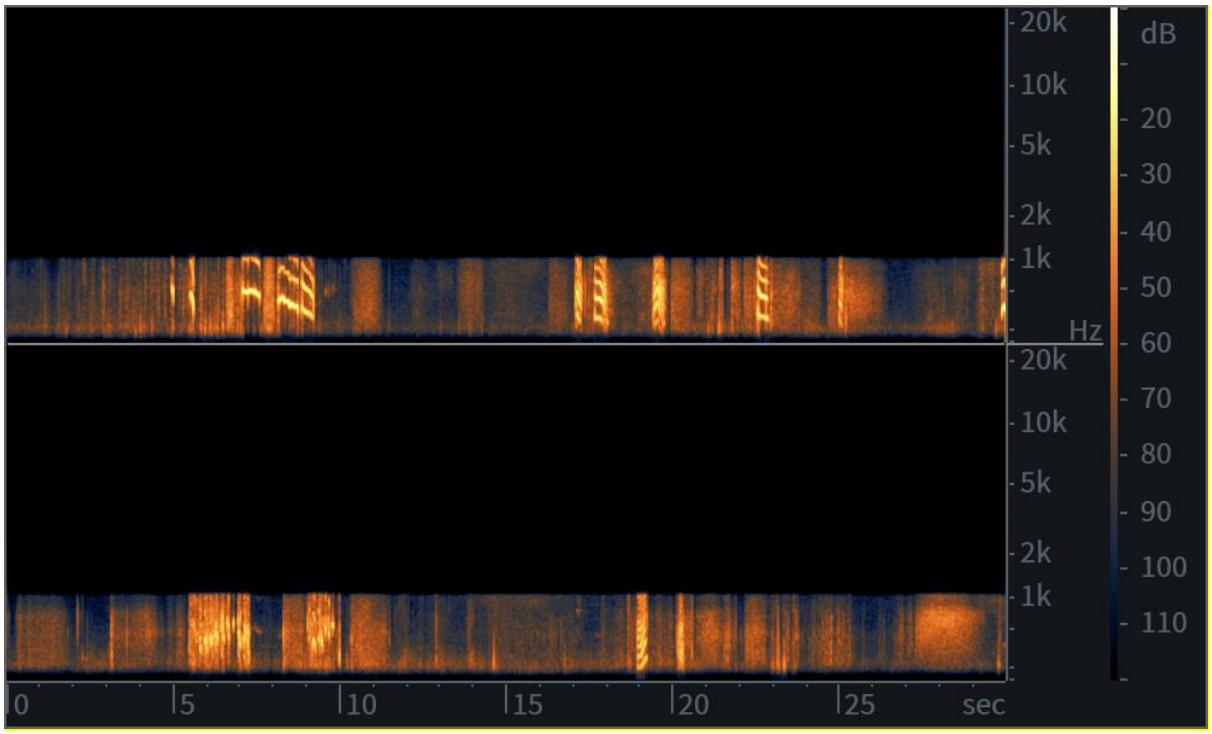

Fig. 3. WDS breath recordings of two subjects in conversation.

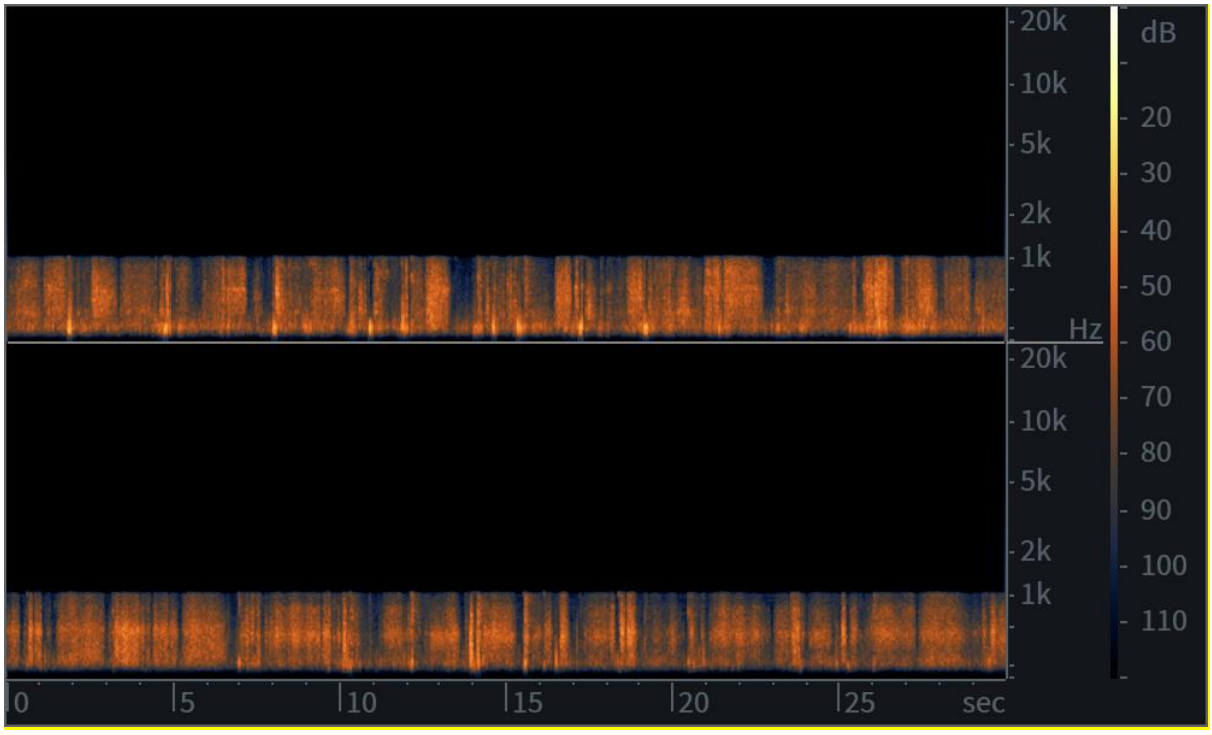

Fig. 4. WDS breath recordings of two subjects throwing back and forth a soccer ball.

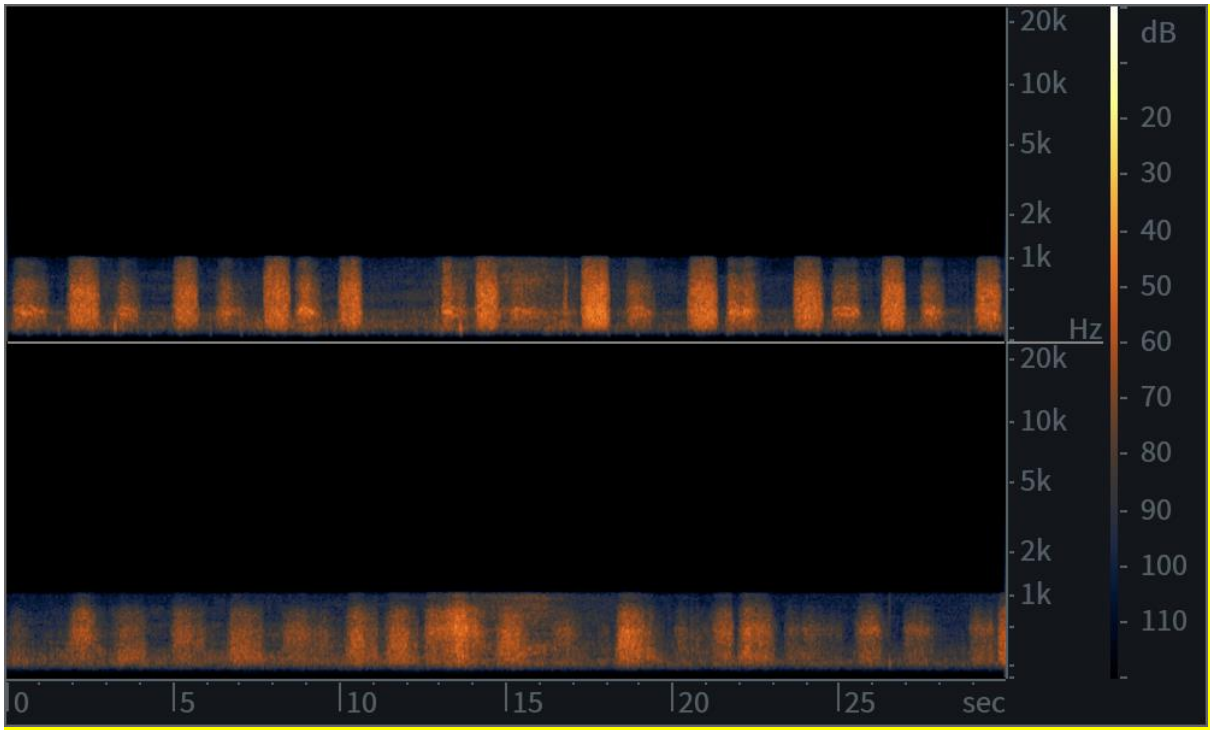

Fig. 5. WDS breath recordings of two subjects jointly solving a puzzle.

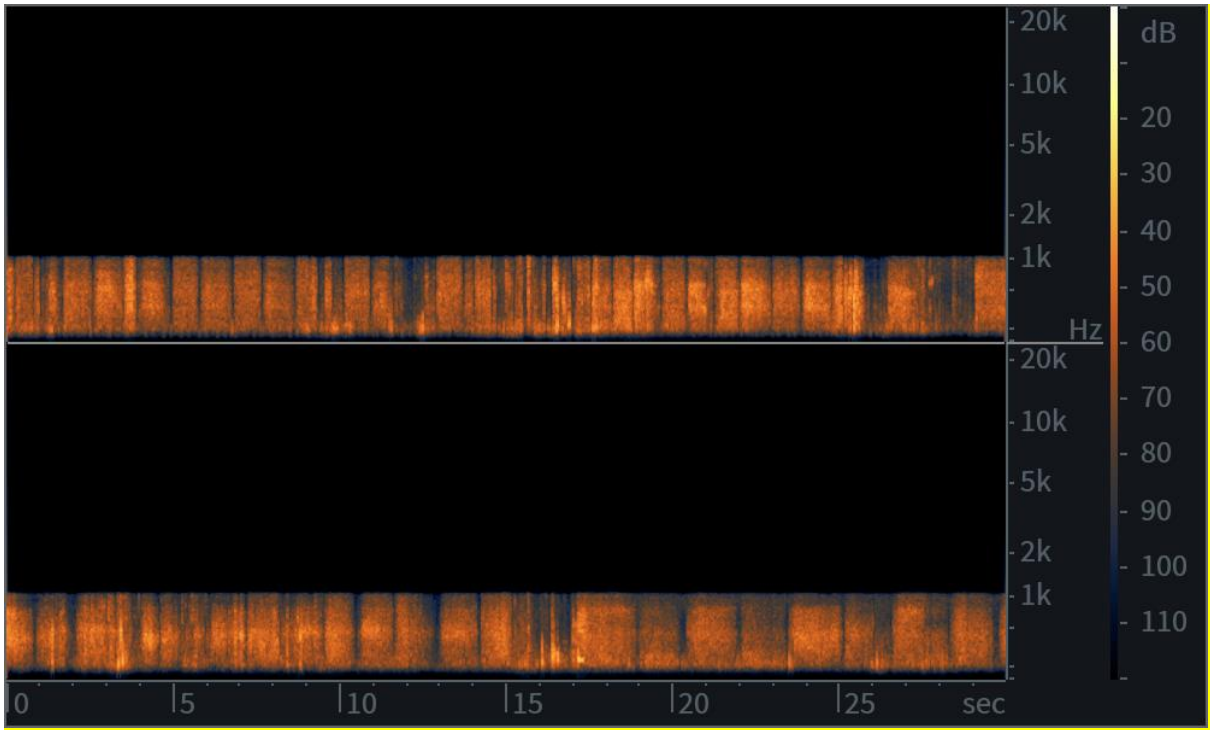

Fig. 6. WDS breath recordings of two subjects, one on top of a barrier (below) helping the other (above) to jump onto the barrier (jump at sec 16-17).

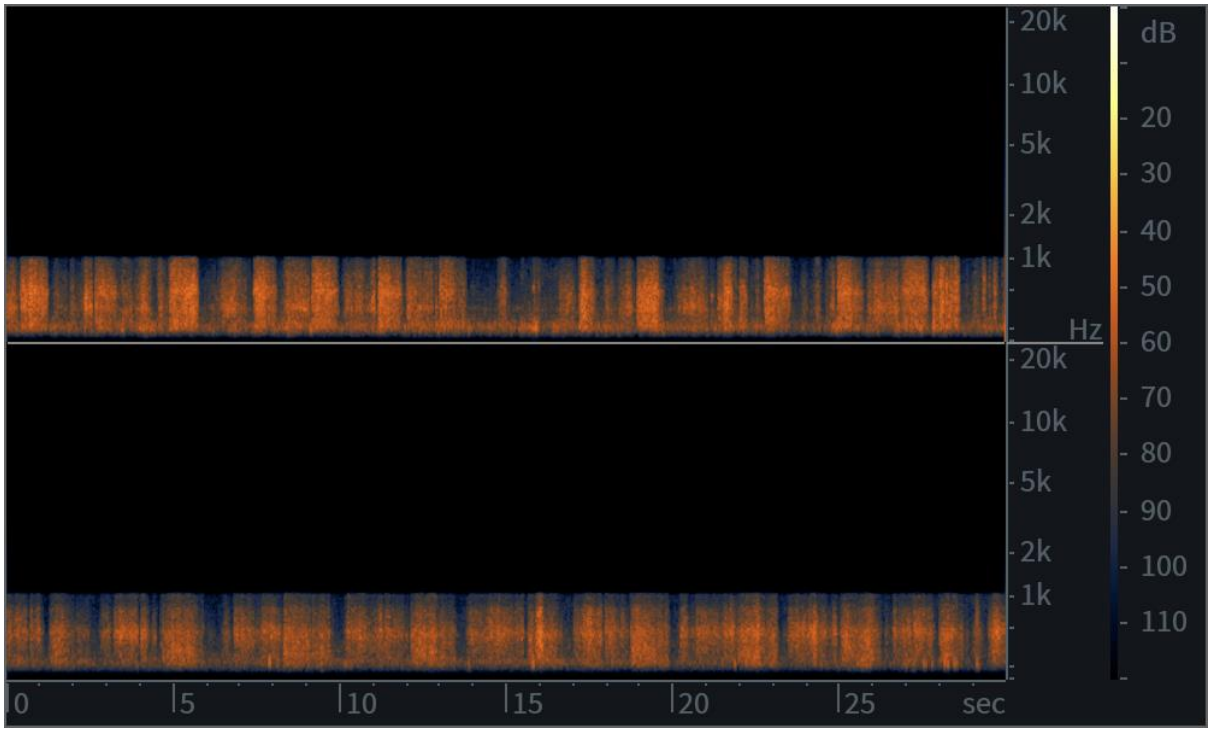

Fig. 7. WDS breath recordings of two subjects dancing Foxtrot.

Transduction

Transduced Data

The breath patterns above illustrate that mental and physical activities are impossible to separate and that subjects are entwined with each other and their environment, for instance, the ground due to the force of gravity. Within the breath there are traces of impulses which belong to what Simondon refers to as the *perceptive relation, the active relation,* and *the affective relation* of consciousness (272). As described earlier, these relations are of the subject and the collective and exist within the suspension of relational transduction. Simondon explains that "[a]t the level of affectivity and emotivity, the relation of causality and the relation of finality are not opposed: every affective-emotive movement is simultaneously judgment and preformed action; it is really bipolar in its unity" (273). Because Simondon views transduction as more fundamental than causality and finality (272) his theory introduces a simultaneous multipolarity.

The three-dimensionality of the spectrograms show these simultaneous relations which, without this transformation into the visual realm, would remain merely on a temporal plane. They represent three dimensions of the sound signals. The x-axis

represents time (in sec) and the y-axis represents frequency (Hz). The various colors represent the amplitudes of particular frequencies at particular times (dB). Through these dimensions the relational processes can be reflected on in a non-linear fashion. Meditating this multidimensional and non-lexical trace of collective breathing might be somewhat representative of the way in which Simondon describes a subject's realization of its own progressive individuation through "successive leaps" (272). In this context, Simondon points out critically Gestalt theory's privileging of the perceptive relation over the active and affective relation. He further claims that this one-dimensionality is closely linked to the temporal plane that amounts to an external logic which does not account for the subject's own temporality (of "successive leaps"). These successive leaps may be traceable more easily in a nonlinear manner through the visualization of frequency and amplitude which reveal patterns of expressions within the breath. These expressions range from pauses and subtle noises to more pronounced activations, and they are in direct correlation with the breath patters of other subjects in proximity.

The ability to trace and record this correlation of multiple subjects' breath patterns while they are in motion via the WDS grants an investigation of subject relations within an environment outside of the laboratory. It further permits to investigate affectively charged intense moments which involve multiple points of view, independent of signification. As I have mentioned elsewhere, these multiple viewpoints can be represented by overlaying the breath signals of various subjects into a monophonic signal which quite literally combines these points of view as illustrated below (Fig. 8).

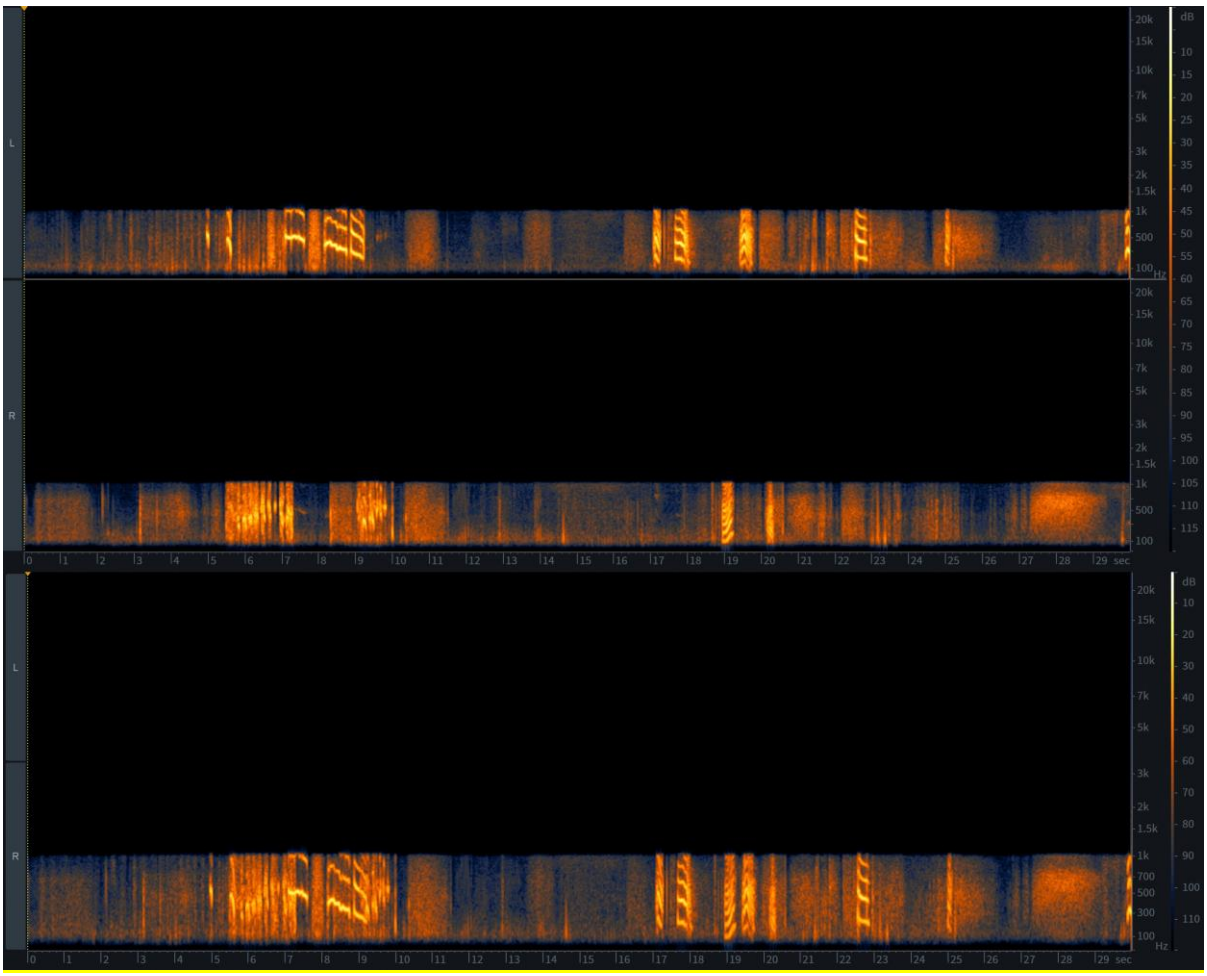

Fig. 8. WDS breath recordings of two subjects in conversation (above channels) overlayed into one monophonic signal (bottom channel).

The monophonic signal (bottom channel) can be read by an ML model as data of the simultaneous viewpoints of a collective and can be compared to different moments in time of the same signal. Since the data of specific dyads is singular and not transferable to other collectives, the already recorded audio signals themselves function as the training data for each particular dyad's successive breath signals. In this case, the oftentimes problematic lack of nuance in the categorized training data of artificially intelligent agents and specifically ML models, is countered by the assertion that data indeed needs to be singular in order to better avoid the inaccuracy inherent in any categorization. This is not an argument for a virtualization of digital computation, computation remains discreet, while the data, on the other hand, is decidedly singular in this experiment. In accordance with cultural theorist Beatrice Fazi (2019), who relies on Simondon's terminology in her effort to find "another

indeterminacy" (23) within computation, this article mobilizes Simondon's concepts of information, individuation, and transduction to offer a critique of representationalism while acknowledging computation's formalist condition.

Sequence Transduction

> "Transduction, then, is not only a path taken by the mind, it is also an intuition, since it allows a structure to appear in a domain of problematics yielding a solution to the problems at hand. In the sense contrary to deduction, however, transduction does not seek elsewhere a principle to resolve the problem at hand; rather, it derives the resolving structure from the tensions themselves" (Crary and Kwinter, 1992, 314-315)

Applying the logic of transduction to an ML model which discerns patterns in the breaths of a collective results in a model which relates the particular to the particular. Counter to both in- and deduction, transduction is a form of transposition which derives inferences directly from a set of examples. Transduction proves useful when training data is limited (Vapnik, 1995, 169). The method is appropriate in this case since regardless of how expansive the training dataset may be, it will remain diverse because affective thus singular data is purposefully included and not categorized, as laid out above. Singular data is challenging to analyze since it is unique. By employing a model which analyses sequences, this singular data is put into context because patterns which are unique to a particular dyad might reappear in similar forms at different times throughout their encounters. The model thereby organizes patterns of breath according to the context in which they appear. When it discerns patterns within a spectrogram like the monophonic overlay of the breaths of multiple subjects above, it analyses patterns of a relation which contain multiple viewpoints as opposed to comparing them. These multiple viewpoints are retained because transduction does not act according to a logic of form, which would result in matching the image of, for instance, a face to the images of faces the model has previously been trained on. A categorization would not attend to the potential of these multiple viewpoints but simply sum the input up to match a preconceived notion of form. Instead, transduction

is acting according to the logic of information which is constantly individuating and readjusting (Crary and Kwinter, 1992, 315).

As a model which organizes around sequences of information, *sequence transduction* does not classify in order to compare fixed formations but, instead, analyses a duration of time. As the sequences change, the inferences adapt simultaneously, and patterns are continuously reevaluated. More common examples of such continuous evaluations performed by sequence transduction models are transformations, such as music transcription or language translation, which may involve both speech and text (Purwins et al., 2019, 207). Usually, this is a transduction from one signification to another. Since, however, Simondon's theory of individuation rests on the notion of information rather than form, it describes a form of semiosis which allows for another stage of amplification, i.e., moments which continue to contain multiple viewpoints despite a completed individuation. He writes:

> "In its separate, recorded, indirectly transmitted aspects, information also expresses a completed individuation and the resurgence of this completion that can extend into other stages of amplification: information is never after individuation alone, for if it expresses a completed individuation, it does so with respect to another individuation that is capable of being completed" (Simondon, 2021, 372)

With reference to the breath, these individuations capable of completion which point to further such individuations, are at different stages of amplification in the sense that they refer to recorded, and thus to a certain extent, fixed elements. Recorded collective breath, however, traces the not yet signified phases of encounters and the way in which they emerge towards signification. The impulses which are present before the collective turns perception into action and affect into emotion are recorded just as well as solutions which signify concrete actions and emotions. Within the WDS recordings they are not of a different order but equally become part of a semiotics performed by both ML model and human interpreter.

Discerning the different stability of these impulses, which are stable together only by means of the recording, is a transduction at work. Some of the impulses will not become solutions but contribute to their formation. The sequence transduction ML

model help to recognize and organize these impulses, and even though this transduction is not as concrete as translating one language to another, it, nevertheless, can be read as a process of transcription. This transcription reveals phases of collaboration within a collective which are usually only recognized in their final formation of a solution. Making these phases of collaboration available is beneficial in the two ways outlined above: it can a) help discern patterns of relation in real-time and thus predict possible future movements, and b) enable a reflection on these patterns of captured intensity by establishing a semiotic system of reference which remains in flux.

Conclusion

The mode of listening introduced by the WDS and ML model, combines binary digital technology and Simondon's logic of individuation which, on the contrary, refuses to operate according to oppositions, negation, and solutions. Solutions are not of primary interest in Simondon's philosophy. His emphasis on relationality suggests a logic which regards every instant as equally important rather than focusing on final terms. The notion of individuation, indeed, implies that there are no final terms but only states in development. Solutions are never final or more potent than the transitional moments which harbor multiple points of view. These transitional phases are under-researched because dominant viewpoints such as substantialism and hylomorphism are based on the binary terms of substance or the lack thereof and form and matter, respectively. Within both of these traditions there are no tools which trace what Simondon terms the *pre-individual* since the individual is taken for granted (Combes, 2013, 2). The phase during which multiple viewpoints are active simultaneously tends to be overlooked in favor of solutions. The WDS and sequence transduction ML model are introduced as one way to approach these pre-individual, intense transitions by technological means.

Tracing intensity and affect within the relations of a collective through their breaths invites a different kind of analysis, a mode of non-binary listening which is not solely goal oriented or concerned with solutions. Gilles Deleuze, who was impacted greatly

by Simondon while formulating his philosophy of difference, summarizes a binary sense of listening as impoverished in the following way:

> "When we interpret differences under the category of opposition and as negatives, are we not already on the side of the listener, even that of the bad listener who hesitates between several possible versions of what was actually said and tries to find himself by establishing oppositions?" (Deleuze, 2001, 204)

Without establishing oppositions but rather multiplicities, the WDS and the sequence transduction ML model make it possible to "listen" and further investigate the intensity of perception and affect in process within the relation of individuating subjects. This mode of listening accommodates what Belgian philosopher Luce Irigaray (1995) has termed "non-reductive" (110) and she specifies:

> "I am listening to you not on the basis of what I know, I feel, I already am, nor in terms of what the world and language already are, thus in a formalistic manner, so to speak. I am listening to you rather as the revelation of a truth that has yet to manifest itself" (117)

She describes listening to a transition with regards to the formation of another subject and to the formation of a relation. When considering each breath as a non-lexical witness to relations, the WDS captures the act of listening alongside the act of being listened to in the collective breathing it traces. Within patterns of breath there are no "active" or "passive" acts, and they can, thus, be described as "non-reductive" in themselves. Amplified breathing recontextualizes a binary notion of communication as turn-taking by foregrounding the constant and simultaneous exchange of intensities during nonverbal communication which renders multiple viewpoints graspable. This study lays out how this oftentimes hidden non-binary dynamic of non-verbal communication can be applied to informatics and how bypassing the logic of "action-reaction circuits" of verbal communication acknowledges and surfaces relationality, affect, and intensity. The discovery of the breath as a modality which traces relational intensity without merely turning it into another signification, the introduction of the WDS, and the sequence transduction ML model which trains on singular data grant a reckoning of collective individuation. Together the breath, the WDS, and the sequence transduction model amount to a non-dualist approach which

combines mathematical and non-binary methods of analysis and which does not merely classify but identifies relational processes as intelligent behavior.

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Manifold Spaces and Patterned Potentialities

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DOI: https://doi.org/10.1344/jnmr.v3i1.38963

Abstract

The research aims at providing a new perspective and methodology to dynamic space setting as a mode articulation for intensity, transformation, and change pointing to more versatile, resilient, and ecological urban assemblages. The anticipation apparatus proposed for architecture and the city is a landscape of Alexandrian Design Patterns and intensive variables that simulates spatial contingencies and connects them with actual bodies as an extended mode of prediction and design. The city is represented as an N-dimensional manifold, a plane of variable dimensionality where its dimensions are used to represent its sociospatial becomings. At the same time, the manifold itself becomes the space of possible states that city can have, an apparatus that structures the city's sociospatial potentialities and dynamically patterns its material reality.

Keywords

Manifold; Design Patterns; City; Intensive variables; Dimensions; Apparatus.

Introduction

This article attempts to better understand spatial materiality exploring and advocating for the agency of technical objects, their meanings and desires being represented and activated. Close to the new materialist informatics' agenda, the affective capacity of space enacted is mobilising materiality's relational, contingent, and emergent nature to provide a new perspective of how the built environment is being produced, constantly made and un-made (Coole and Frost, 2010, p.29). Thus, allowing for space to be understood, visualized, and potentially designed in an open, integrated, and reversible format. The research provides a new perspective and methodology to dynamic space setting as a mode of feeling and information-sensing for architecture and the city. The *anticipation apparatus* proposed simulates spatial contingencies and connects them with actual bodies as an extended mode of prediction and design. Recognizing the materiality of form and the forming of matter, design is in this respect operational, prioritising production processes to end results (Sauvagnargues, 2015, p.74). Using information as a form of matter, the apparatus systematizes possibilities of appearance and capacities for spatial transformation (Passia and Roupas, 2018, 2021).

To think in terms of not *what space is* but *what it can be*, the research is drawing from the Deleuzoguattarian concept of *the virtual*, "a mode of reality implicated in the emergence of new potentials" (Massumi, 1998, p.16). This mode is *the reality of change and continuous transformation*, entailing a shift in the very object of the architectural design process. While traditionally invested in form as a beginning and end result, architecture within the topological turn is about thinking in terms of possibilities for change, monitoring how form may evolve and adapt (Massumi, 1998, p.18). In this paradigm, according to Massumi, form is not conceived but is coaxed out from its virtuality, at the same time sweeping the architect away from its creative primacy to assume a new role as a catalyst or mediator in this process(es) of becoming. An important shift from *what the form is* to *how it can be deformed* takes place, where "form emerges from virtualities being ceaselessly actualised" (Marenko, 2015). To grasp what constant change means for the architecture discourse, the research taps into topology as a pool for working concepts and a conceptual

vocabulary. Space then becomes a topological engine of potentialities, recursively calculating differentials and uncertainties, an *anticipation apparatus* (Parisi, 2012, p.168; Massumi, 2007).

Using topological media for the study of spatial dynamics provides tools, models, and concepts for understanding and designing of space that are neither typological nor morphological. Reconceptualizing the built environment in these terms allows to explain how and why space changes at different levels and in different ways; how space is fully intensive rather than extensive, that is, spaces being evaluated in terms of their production processes and possibilities for change; how space is constituted in relations rather as having some essential properties, values and norms; and finally, to accept spatial change as affirmative and immanent rather than negative and externally defined. The anticipation apparatus is a mode of articulation for *intensity, transformation, and change* as other modalities of spatial relations and dynamics of structure (Lury et al., 2012, p.4). It provides to architecture a set of working concepts for thinking and conceptually experiencing the recursive process of the actualisation of space; a movement through registers: *from the virtual to the actual via the intensive*.

To elaborate on the intensive reality of space while at the same time remaining connected to the actual register, we turn to *patterns*. As patterns are tied into the morphogenetic processes that shape them (Closkey and Vandersys, 2017, p. viii), they render visible the intensive nature of these processes that in turn give rise to actual substances (Bonta and Protevi, 2014, p.16). To that end, the research points to architect and design theorist, Christopher Alexander and his 65 Design Patterns[1], as presented in his book, *A Pattern Language: Towns, Buildings, Construction* (Alexander et al.,1977). *Design Patterns* are used to differentially define space as variable and intensive media advocating for an important ontological shift *from objects to processes and material fields* (Sha, 2013, p.90). At the same time, space on these fields can be perceived as relational, intensive, variable, and continuous.

[1]The total number of invariant Patterns in Alexander's archive are 83. For the purpose of this experiment, Patterns referring to construction – ranging from 205 to 253 – have been left out. The sample selected contains the following 65 Patterns:1,3,8,9,11,14,21,22,30,31,36,37,40,41,46,48,49,51,52,53,60,61,67,69,79,80,87,88,95,98,10,104,105,106,107,110,112,115,117,119,124,127,129,130,139,140,141,148,155,159,160,161,163,167,168,171,172,174,179,180,183,188,190,191,197.

To investigate the virtuality of space, the concept of a Deleuzian *multiplicity* is introduced, a philosophical concept equivalent or close to a mathematical *manifold* (DeLanda, 2005, p.10), now pointing to architecture and the city. As the manifold's architecture gets progressively defined, Alexander's Design Patterns organize a relational field of emergence where space is perceived as *assemblages of variables* and specific Design Patterns explain its possible mutations. The manifold is used to change the understanding of existing design problems and also address their changing conditions without the need to refer to subsisting dimensions. Constructing new cartographies of diagrammatic connections of both existing and possible objects, the manifold is actively marking continuities, similarities and connectivities.

The basic plan of this essay is as follows. The first section introduces Alexander's Design Patterns as relational frameworks that explain and shape recurring processes, relationships, and structures regarding space. It points to their relevance to articulate both the city's production processes and its possibilities for change. The second section deals with the theoretical framework needed to think about moving through the different ontological registers, focusing on maps and manifolds. It explores the different spatial regimes, the beings that inhabit them and their implications in the actualisation of space. The following section elaborates on processes of making manifolds drawing from manifolds' relations to science and philosophy. It provides a set of working concepts and a conceptual language to explore manifolds and the production of the multiple. The two subsequent sections follow through the production of the anticipation apparatus directly drawing from Daniel Smith's deconstruction of the Deleuzian concept of Life as a non-organic and impersonal power (Smith, 2012, p.189-221). For the first part, "the power of abstraction" is elaborated on outlining an extraction process on Alexander's archive of Design Patterns. At the end of this part, intensive variables sampled from the Design Patterns become the apparatus' elements. In the second part, "the power of creation" and designs the apparatus' architecture organizing its elements into a vectorial field of connectedness composed of Alexandrian Patterns and intensive variables are explored.

Design Patterns

Christopher Alexander attempted to establish a design methodology aiming at a generative production system for architecture. His work has defined the development of architectures of information (1960-1985) by applying informational processes and technologies in architecture (Steenson, 2014, p. 3). By documenting the design problem as an informational problem, he visualised the informational example in architecture and constructed a generative system for architecture, as described in his book *A Pattern Language: Towns, Buildings, Construction*. His most important contribution lies in describing architectural form through visual information structures – the *Design Patterns* – in documenting them as solutions to recurring problems of the built environment and placing architectural form under the heuristic understanding of architecture as a problem to be solved. He also proposed shaping architecture into networks and languages of Design Patterns under a generative logic, his Pattern Language.

Patterns are relational frameworks that both explain and shape recurring processes and relationships while giving rise to actual material structures (Closkey and Vandersys, 2017, p.7i). They have associative properties in that they are made of multiple entities, able to be further analysed into their constituent parts. Patterns shift the focus away from entities towards their relationally and connectivity. Each Design Pattern, according to Alexander, is a generative system: a kit of parts with rules about the way these parts may be combined (Alexander, 1968, p.605). As Bateson explains,

> We have been trained to think of patterns as fixed affairs. In truth, the right way to begin to think about the pattern which connects is to think of it as primarily a dance of interacting parts and secondarily pegged down by various sorts of physical limits. (Closkey and Vandersys, 2017, p.46)

By shifting his interest from the form's elements and focusing on the relationships between those elements, what Alexander proposed is a significant upgrade regarding the flexibility of form and its ability to exist as a product of differentiation, to change and create iterations of oneself.

At the same time patterns are tied into the production processes that shape them. They are the "surface" expression of underlying interactions and movements forming

the physical conduits, pathways, and networks for energy, materials, and forces to actually flow and interact" (Closkey and Vandersys, 2017). Usually, as Bonta and Protevi point out, "the extensive properties of actual substances cannot be used to predict the virtual structures of intensive processes, because the extensive properties *hide* the intensive nature of the morphogenetic processes" (Bonta and Protevi 2004, p.16). To that end, Design Patterns allow for an important shift: they render visible the intensive processes that produced them while at the same time actively connecting them to the extensive properties of actual substances. In Alexander's archive, each Pattern is described in the form of a three-part rule, expressing a relation between a certain context, a problem, and a solution (Fig.01). Each Pattern's internal structure lies in its solution where communications between its component parts and rules take place, resulting in the Pattern's actualization (Deleuze, 1993, p. 100). The solution "describes the field of spatial and social relationships which are required to solve the stated problem, in the stated context" (Alexander, 1977, p.xi). It consists of an instruction along with a diagram that visualises the solution, with labels to indicate its main components. Each component is a process rather than an end product, occurring gradually, at different speeds and rhythms.

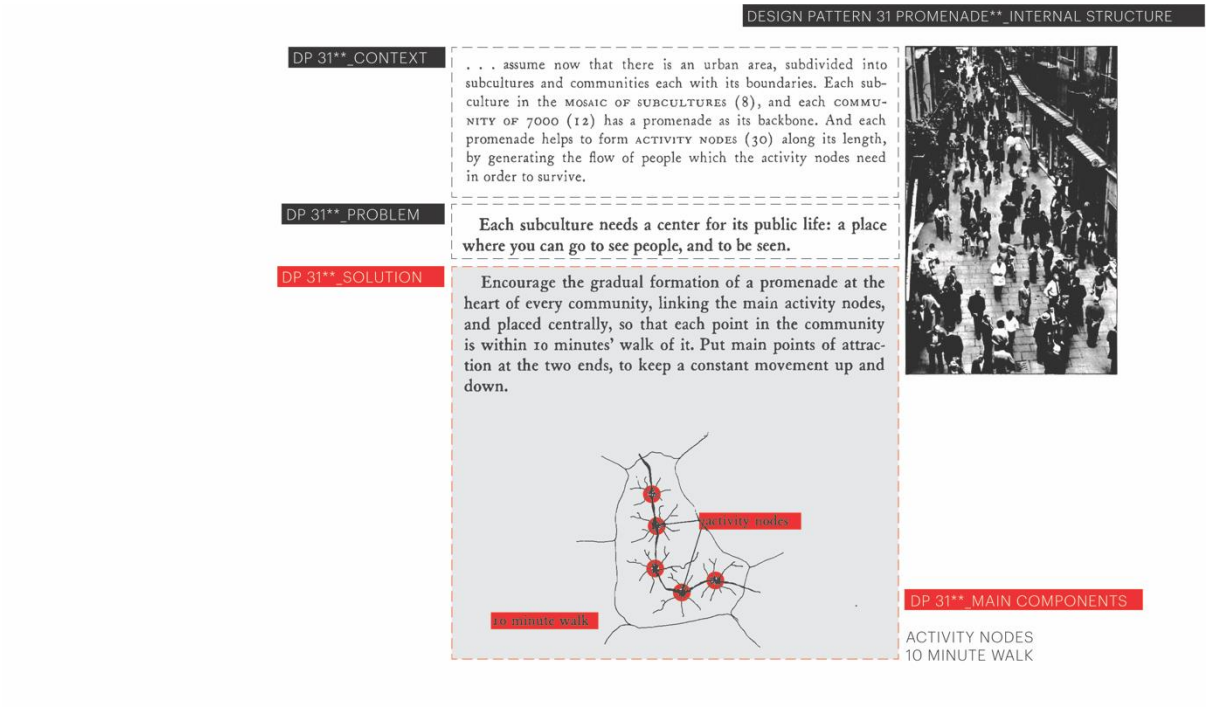

Figure 01. Design Pattern 31 Promenade**_Internal structure (Passia Y. and Roupas P., 2021)

Design Patterns present a valuable reservoir to articulate space in a perpetual state of becoming so as to enable deformation and change . They are immanent in the physical world, that is, they are internal and normal. They are constituted in relations rather than being categorial and at the same time they allow us to tap into the intensive dimension of space while remaining closely affiliated to the extensive world. Being formal, material, or temporal recurrences, Design Patterns are given the modal status of the possible while their sum points to all[2] *the possibilities of space,* all the possible states space can have.

As the research aims at continuity and deformation to allow for spatial change and reversibility, it focuses on how Design Patterns can become fully intensive, variable, and associable media and on how to topologically interconnect them in a continuous format (more on this in the last two sections of the paper). Pointing to the Patterns' components rather than to Patterns themselves, assemblage dynamics radically enhance their variability, creating ever-new connections and interactions among them. While in Alexander's Pattern Language active links are created only among Design Patterns, now the focus is placed on their component parts. This way, one can now directly tap into the dynamics of particular processes that shape and "unshape" any Design Pattern. At the same time, components are now free to topologically interconnect without referring to their respective Patterns. For example, an important component of Pattern "31.Promenade" is *public density*, also used by "Patterns 3.City country fingers," "21.Four-story limit," "30.Activity nodes," "61.Small public squares," "139.Farm-house kitchen", and "179.Alcoves." These Patterns now form a cluster of design solutions that focus on the process of *public density*, at different scales and levels of detail. Their multiple topological interconnections become a means to introduce new continuities into the discontinuous world, exploring how space can be made and unmade, the concepts, paths, and drives that guide its various actualisations (Lury, Parisi, Terranova, 2012, p.4).

At the same time, Design Patterns are here theorized as spatial assemblages composed of heterogeneous elements – themselves being parts of larger assemblages – that enter into relations with one another while their components'

[2] Design Patterns' archive is itself in a process of becoming as new Patterns are being continuously documented. In that sense, both their "sum" and "all" are used in a non-reductive way.

ability to engage is contingent. Moving away from conceptualizing systems as seamless wholes, assemblages provide "the possibility of analyzing both the contingent interactions between parts as well as the emergent properties of the complex whole" (DeLanda, 2006, p.10). In this context, any Design Pattern's component may be detached from its assemblage and plugged into another where it forms different interactions. Such an approach further emphasizes fluidity, mutability, and interchangeability of spatial components, producing evolving systems that interact with each other.

Allowing for components to attach themselves to existing patterns or detach from their assemblage states is formative for the apparatus' plasticity and capacity to produce ever-new Design Patterns for sensing and calculating spatial data. Let's postulate the component of public density detaching itself from Pattern 31, an action that would significantly alter the design solution towards a promenade that is less public and more private. This could result in a variation of Pattern 31 or — as more components are being detached or attached — a totally new Pattern potentially able to address novel or emergent design problems rather than pre-set ones. This becoming-nomadic of Patterns marks the process of their transformation "into the active production of multiple forms of belonging and complex allegiances" (Braidotti, 2017, p.301). Systematising space and the built environment in terms of variable components and intensive processes while at the same time capitalising upon them as mechanisms for spatial continuity, advocates for design that is open to alternatives, revisions, and contingencies.

From Virtual to Actual via the Intensive: Maps, Multiplicities, Manifolds

As we are invested in exploring the material becomings of space, its spatial and social tendencies and capacities not yet actualised but fully real, this part will focus on better understanding the actual, the virtual and the intensive, in terms of their modal status, their interconnections and respective representations. According to writer, artist, and philosopher Manuel DeLanda, the three ontological aspects that constitute the Deleuzian world are *the virtual, the intensive and the actual* (Fig.02). They should not

be thought of as levels but as moments in a process of unfolding[3] (Bonta and Protevi 2004, p.16). At the same time, they present three different assemblage states: moving from the virtual to the intensive and to the actual, there occurs a gradual phase transition in which *quality changes into quantity*. We can imagine the virtual as a continuous space with no differentiation that progressively becomes discontinuous into intensive and gradient regimes (DeLanda, 2010, p.133) to give place to the intensive. In turn, the intensive further differentiates into actual spaces and substances. According to Delanda, the three domains foster significantly different beings. While the actual is the site of *final products* with their extensive and qualitative properties, the intensive is the site of *production processes* with their intensive differences and critical points of change. The site of the virtual is the scaffolding of these production processes, a structure that explains *regularities in both the processes and the products* (DeLanda, 2010, p.128).

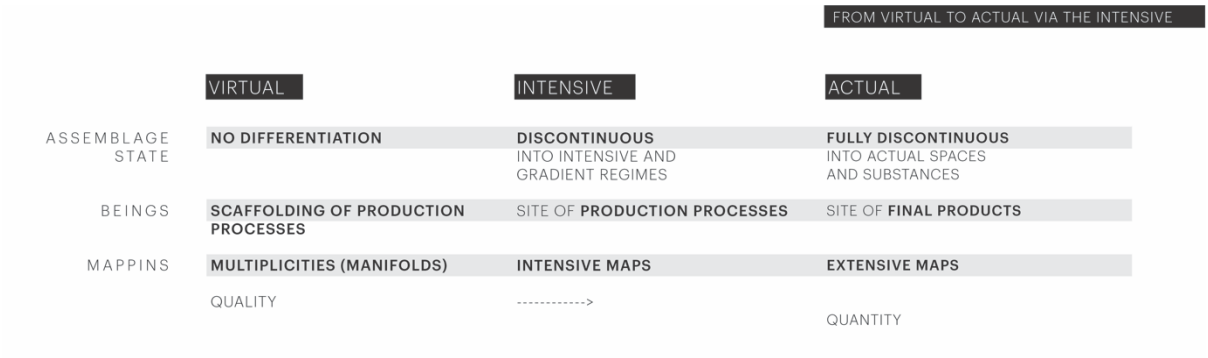

Figure 02. From Virtual to Actual via the Intensive (Passia Y. and Roupas P., 2021)

When pointing to architecture and the city, what do final products, processes or their intricate scaffolding mean and how do they look? To further explore these three domains we turn to their respective mappings that are significantly different. *Extensive maps* capture spaces that are bounded by natural and artificial extensive boundaries that extend in space up to a limit marked by a frontier. These spaces have extensive or metric features, defined both by their extensive and qualitative properties. They are the final products e.g., the city's actual spaces such as the promenade depicted in the

[3] Bonta and Protevi (2004, p.16) further explain the thee registers "as moments in a process of unfolding marked by symmetry-breaking cascades".

indicative picture of Pattern 31 (Fig.01). Intensive maps**,** on the other hand, capture differences in the intensity of a particular property as well as the dynamic phenomena that are driven by such intensive differences. (DeLanda, 2010, p.115). The spaces captured on these maps are non-metric or topological, intensity zones "bounded by critical points of change, whether in temperature, pressure, gravity, density, tension, connectivity and more, and define abrupt transitions for the state of natural and artificial objects that inhabit them" (Buchanan, 2005, p.80). Intensive maps capture spatial gradients **—** their intensity zones and critical points of change — and explain how space is produced. While all Design Patterns are processes and hence intensive in that respect, only six Patterns within Alexander's initial archive capture spatial gradients and intensity zones. Their structure is gradient-like and their diagram maps a spatial relationship organised into intensity zones. Such an example is Pattern "36.Degrees of publicness" (Fig.03), which maps intensive relations of *decentralisation* and *concentration.* Its component parts are significantly different. Spaces on intensive maps are morphogenetic processes e.g., social, material, spatial, political etc. In these terms, *intensive and extensive spaces are genetically connected*: the former are the site of processes that produce the latter. Thus actual space as we experience it is there as a result of its many gradients.

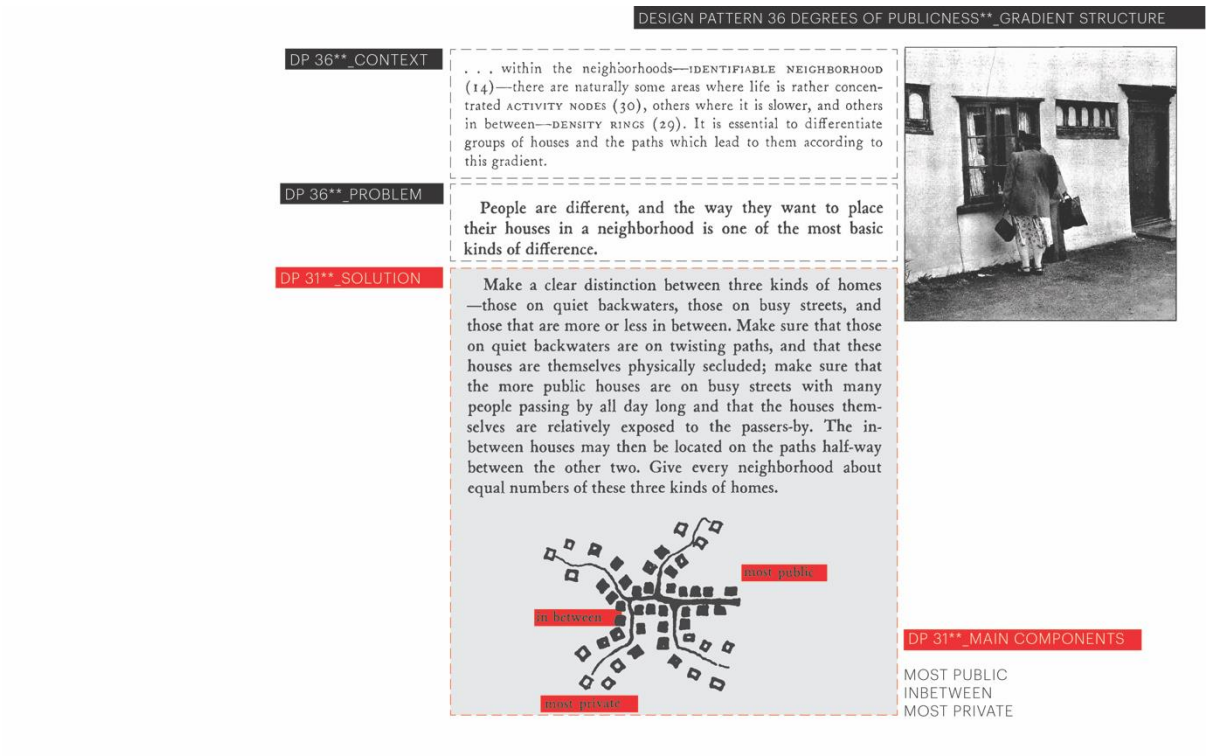

Figure 03. Design Pattern 36 Degrees of Publicness**_Gradient structure (Passia Y. and Roupas P., 2021)

Virtual maps we postulate to be quite different, ideally continuous and fully qualitative assemblages. Virtual maps capture the structure of possibility spaces, the dynamical landscape of the city's complex system, including its patterns of behaviour and the thresholds where it changes patterns (Bonta and Protevi, 2004, p.19). Virtual maps are genetically connected to intensive maps too since they produce them as they unfold. The virtual domain is the site of potential transformations that structure the city's intensive production (or morphogenetic) processes. *Thus actual space as we experience it is there as a result of its many gradients, and its many gradients is the result of their virtual structure.* Deleuze conceives of such virtual structures as *multiplicities*. According to DeLanda, "multiplicities specify *the structure of spaces of possibilities*, spaces which, in turn, explain the regularities exhibited by morphogenetic processes" (DeLanda, 2005, p.10). Drawing maps of those structures would get us thus closer to our apparatus, reconceptualizing space and the built environment as a dynamical landscape of potentialities.

To that end, the concept of *the manifold* is introduced, a philosophical concept equivalent or close to a *mathematical* manifold (DeLanda, 2013, p.10). Dynamical

systems use manifolds as their models to provide a scaffold for their intensive processes. Manifolds are closely related to the concepts of “state space” or “phase space” and to the concept of the virtual as the modal status of the set of possible states of the system along with the probabilities of attaining a particular subset of those states. A manifold is an abstraction of Euclidean space, an N-dimensional topological surface composed of local subspaces without the need for a global embedding system. On manifolds, one can specify neighborhoods and articulate their proximity — categorial, spatial, temporal — without having to use rigid lengths or metric quantities (Sha, 2013, p.100). In that sense, manifolds are topological structures that represent continuous and continuously varying fields as an approach to articulate objects as they shape and dissolve in those fields (Sha, 2013, p.90). Relations of continuity and connectedness in those fields are established in terms of vectors and vectorial gradients (Lury, Parisi, Terranova, 2012, p.23). The manifold can be then used to articulate how space is produced as well as capture the different possible states in which it can exist. Instead of thinking of space through points and their connections, the manifold’s points might be entities, events, or spaces, further exploring the flexibility of space. Through the manifold, it becomes possible to measure the entities’ proximity by establishing connectivity protocols and measuring their communication patterns. Transformations of both the entities on the manifold *and* their relations are open and immanent instead of causal and linear, radically maximising the variable character of space (Lury, Parisi, Terranova, 2012, p.8).

Making Manifolds: Terms, Concepts, Techniques, and Methods

To make a manifold for space and the city, we will explore two distinct discourse areas that delve into *the production of the multiple* (Fig.04). Each shall provide a very elaborate framework but also working concepts and the vocabulary able to enrich our world-view of manifolds and their production processes. The first, more scientific discourse draws primarily from manifolds’ connection to “state space”, a concept developed by mathematician Henri Poincare towards the end of the 19th century, to provide a visual representation of the behaviour of dynamical systems (Bonta and Protevi, 2004, p.17). From that theoretical ensemble we will mainly focus on *a step-by-*

step method on how to construct such a "state space" (Bonta and Protevi, 2004, p.14-20; DeLanda, 2005, p.85). The second and more philosophical discourse, though not entirely disconnected or separate from the first one, draws on Deleuze and Guattari's terms, concepts and methods as *processes of making a manifold*. These include but are not limited to, their Cartography method (Bonta and Protevi, 2004, p.22), Life as a non-organic and impersonal power (Smith, 2012, p.189-221), and the term "Concept" as a multiplicity (Deleuze and Guattari, 1994). Often, terms of the first discourse may be referenced in the second but not in the same way as in science. The philosophical discourse's main contribution lies in its persistence on providing *an ontology of variable entities* — be they bodies or concepts, organic or non-organic — as purely intensive or schizoid bodily assemblages (Smith, 2012, p.209).

Figure 04. The production of the multiple: terms, concepts, techniques, methods (Passia Y. and Roupas P., 2021)

Postulating on manifolds as "state spaces"[4], geophilosopher Mark Bonta and philosopher John Protevi (Bonta and Protevi, 2004, p.17) provide us with a step-by-step method of constructing such a "state space". We attach it along with some notes

[4] According to Manuel DeLanda, the process of making a manifold consists of two parts. First, "each of the manifold's dimensions is assigned values from one of the degrees of freedom of the system itself "(DeLanda, 2005, p.85). Then the manifold becomes its "state space or phase space" (DeLanda, 2005, p.14).

on our end for each step, drawing primarily from the second and more philosophical discourse, as a basis for the city's manifold-like apparatus.

1. Identify important aspects of a system's behaviour, which are called its "degrees of freedom".

a. The dynamical system at stake here is space and the city while its important ways of changing are the components of the assemblage, the elements of the multiplicity (Bonta and Protevi, 2004, p.22). To establish the city's ways of changing, the Deleuze and Guattari's Cartography method advises that we *use measurements of both its extensive and intensive properties of the system*, that is, properties of both actual city spaces and of their production processes (Bonta and Protevi, 2004, p.16).

b. Exploring the virtual scaffolding of intensive processes that give rise to the actual city along with its possible divergent actualisations, points to "placing the variables themselves in a state of continuous variation" (Deleuze, Guattari and Massumi, 2005, p.369). Then, the city's spatial intensive variables — connecting both to its extensive and intensive properties — are to be placed in variation.

c. The system's components are themselves assemblages at different levels or moments of unfolding which in turn means that each component is expected to have its own "degrees of freedom". Or as DeLanda notes,

> "the building blocks used as components of an assemblage are themselves assemblages operating at a smaller scale, and we should be able to give causal mechanisms defining the processes that actualized them, as well as the mechanism – independent structure of their own possibility spaces." (2010, p.102)

A multiplicity's components, spaces or regions of intensity are gradients which means that they are themselves state or phase spaces defined by their respective dimensions or "intensive ordinates" (Deleuze and Guattari, 1994). Both the system and each component claim for their own variable

dimensionality thus defining the system's patterns of behaviour at different levels.

2. Construct a space with as many dimensions as the degrees of freedom of the system under consideration.

a. By dimensions, we mean the variables or coordinates upon which a phenomenon depends (Deleuze, 2004, p.182). Then, the dimensions are zones of intensity used to represent properties of a particular physical process or system (DeLanda, 2005, p.13). The apparatus will be a model of the spatial and social processes that produce the city, its dimensions directly connecting to these morphogenetic processes. The term "model" is here used in the context of a becoming or a process, in constant variation.

b. Dimensions, as well as degrees of freedom in this context, appear to be discrete or constant. A Deleuzian multiplicity however, has a variable number of dimensions (DeLanda, 2005, p.12) to accommodate for both the complexity of the system under observation and its emergent properties. In the next section, we will use Design Patterns and an extraction process to set dimensional surfaces or better yet, explore the principles of their dynamic genesis.

c. We have established that both components and dimensions should be placed in a state of continuous variation. The city, like a schizoid body, knows no constant organs or dimensions, either in function or position. And most importantly, organs or dimensions can be experienced as pure intensities capable of being linked together in an infinite number of ways (Smith, 2012, p.208). The same holds for the variable components of each dimensional surface. To that end, Design Patterns will be transformed into intensities capable of producing a vast array of sociospatial processes regarding the city, thus giving rise to highly dissimilar final products and actual spaces.

3. Represent each state of the system by a single point with as many coordinates as there are dimensions.

a. Coordinates or values, as well as dimensions in this context, appear to be discrete or constant. However, they are potentially always changing in number and/or composition as the system evolves.

b. The term “coordinates” relates to both values and variables upon which a phenomenon depends.

c. The idea of the single point relates to the manifold being a “continuous, defined multiplicity” (Deleuze, 2004, p.182). By continuous, the manifold refers to the differential calculus which means that changes in a variable relate to changes in all other variables at the same time since variables are topologically bonded. The “defined” part refers to the elements being defined by these relations of reciprocal determination. As entities on the manifold — on all scales — are reciprocally determined, a change in them means a change in the multiplicity “in its order and its metric" (Deleuze, 2004, p.182).

4. Follow the movement of the point, which represents the changing states of the system as it produces a trajectory through state space, with time as a running parameter.

a. Once the apparatus is an N-dimensional, continuous, defined multiplicity, its network topology will allow us to explore how its form directly connects to its function. Patterns of connection between its variable elements will be able to advocate for their communication possibilities. Moving on the manifold’s paths and gradient neighbourhoods will further conceptualise space towards its possibilities for change.

5. Attempt to solve the equations governing the trajectory and thereby predict the system's behaviour.

a. The apparatus in the form of a manifold postulates on the city’s possible spatial and social becomings acting as the city’s virtual scaffolding. Connecting the city’s possible futures to an array of intensive production processes, and to actual extensive and qualitative spaces, it monitors spatial change and contingency. The apparatus stands for a topological approach to spatial

> dynamics, a complex model of predictability, where the term "model" concerns an extended model that calculates becomings and mutations.

In the case of the apparatus designed for space, its dimensions will be assigned values based on the relevant ways that *the city* can change while the points in the manifold will represent all the possible states the city can have. Following this as a making-agenda for the city's "state space", we shall attempt to better define the apparatus in terms of its *dimensionality and structure* returning to the manifolds' more scientific background. The apparatus — a multiplicity to be modelled into a manifold — is an N-dimensional topological surface, its number of dimensions being equivalent to the relevant ways the city can change, the variables or coordinates upon which it depends. The elements of the multiplicity or spaces in the manifold, represent all the possibilities for a given system, or in the case of the apparatus, all the sociospatial possibilities of the city.

By now, we have a much clearer idea of how a manifold for the city looks like and how it is expected to behave. At the same time, we know more about its components or elements regarding their optimal character and structure. As we move forward in designing the apparatus, for the version presented here, we shall focus on the production of multiplicities as presented by philosopher and researcher Daniel W.Smith, in his essay " 'A life of Pure Immanence': Deleuze's 'Critique et Clinique' Project" (Smith, 2012, p.189-221). His focus in this essay is on the Deleuzian concept of Life as a non-organic and impersonal power while the production of the multiple, according to Smith, entails two tasks: to *obtain pure singularities* and *establish relations or syntheses between them,* so as to produce a variable whole that would be the ''effect" of its disconnected parts (Smith, 2012, p.198). For the former task, *a power of abstraction* is extracting or producing such genetic elements while at the same time placing them in a state of continuous variation. After the end of this process, each Design Pattern is designed as an N-dimensional manifold, the dimensions corresponding to the variables of its extensive and intensive properties. At the same time, a set of 88 intensive variables are extracted from Design Patterns to become the apparatus' elements. For the latter task, *a power of invention* is creating ever new relations between these genetic elements (Smith, 2012, p.218). After the end of this

process, the manifold's elements interconnect to exhibit the full repertoire of their communicational tendencies and capacities.

A Power of Abstraction: From Design Patterns to Intensive Variables

To move away from the city's metric spaces of extensive and qualitative properties and thus move closer to its potentialities of becoming — its tendencies and capacities — we first need to tap into the city's intensive realm. To that end, *intensive parameters* that define the city's important "ways of changing" are thoroughly examined and mapped. Focusing on Alexander's initial archive, each invariant Pattern is evaluated in terms of *its extensive and intensive properties*. Pointing to each Pattern's problem analysis and solution — for which Alexander provides a guideline and a visual diagram — *a set of variables* is extracted from each Pattern. The variables are each Pattern's "ways of changing", the structure of its N-dimensional surface or manifold. These parameters are intensive ordinates to be construed as *processes*, that is, not as adjectives or nouns but as verbs or infinitives (Sha, 2013, p.148) (Fig.05). For example Design Pattern "8.mosaic of subcultures", has several parameters pointing to its generation such as *spatial demarcation* or *character*. They are to be thought of as *to spatially demarcate* or *have/enable a character*, pointing to their internal conditionality and textured internal structure. Through such an extraction process, each Pattern establishes its degrees of freedom — the variables responsible for its actualisation — and is advocated for as an *assemblage of variables*. The variables map the textured gradients of each Pattern's becoming, its phase or state space. After the end of this process each Design Pattern possesses a definite dimensionality, that is, a specific number of relevant ways of changing while the population of Patterns is dimensionally heterogeneous. Through this process, a total of *88 variables* have been extracted or sampled from Alexander's Design Patterns and a list connecting them with their respective Patterns is produced. Through this list, each intensive variable is associated with the Design Patterns responsible for its actualisation. After the end of this process, intensive variables have been extracted from the city's extensive and intensive unfoldings.

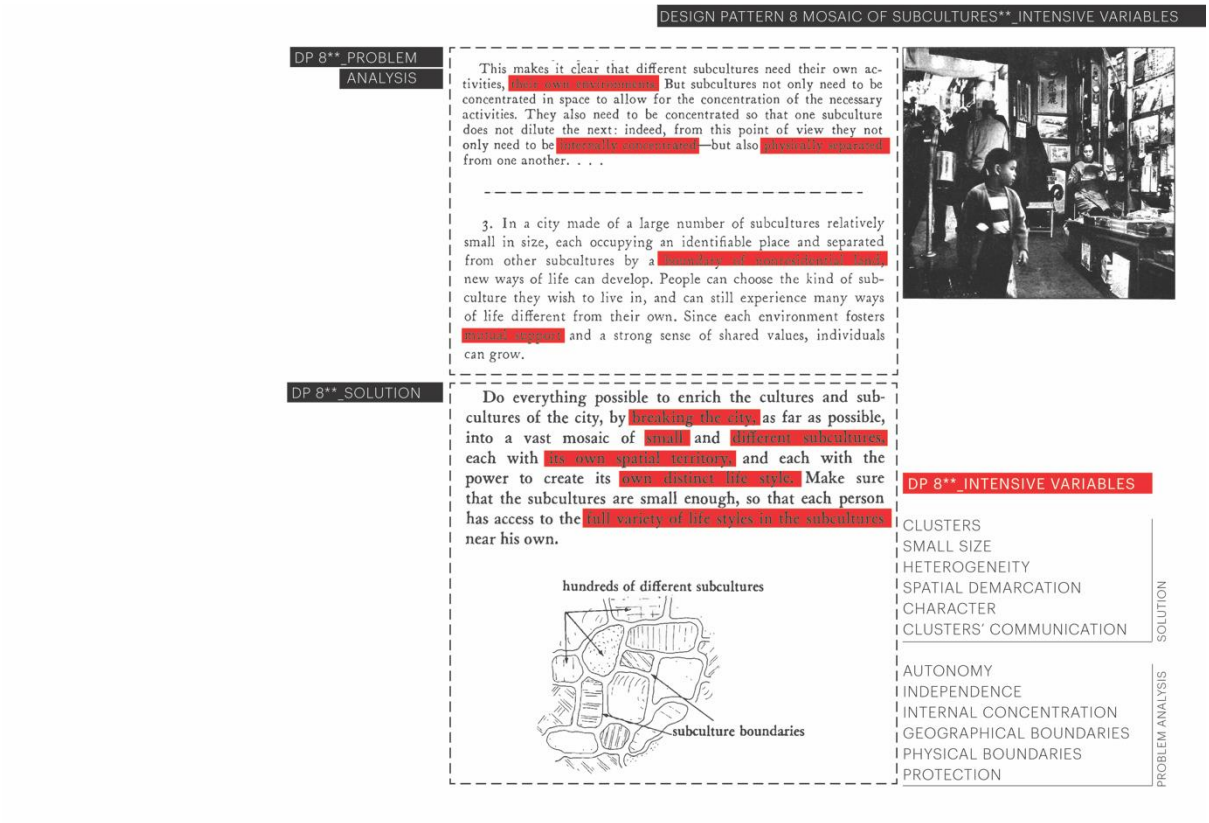

Figure 05. Design Pattern 8 Mosaic of subcultures**_ Intensive Variables (Passia Y. and Roupas P., 2021)

Intensive variables or "intensive ordinates" (Deleuze, G., and Guattari, F. (1994), p.20) become the *apparatus's elements* and are introduced onto a surface in space attributed solely to their productive relationships, interactions, negotiations, and exchanges (Fig.06). On that surface, they are free to assemble and reassemble anew, live or die, vary at different speeds and rhythms, as they exercise their communication properties, they exhibit their unactualized tendencies and manifest their full range of capacities. This surface, an N-dimensional manifold, assembles spaces of heterogeneous dimensionalities, allowing them to co-exist and should be construed *as a plane of variable dimensionality.* Furthermore, its heterogeneous population is itself N-dimensional as each Design Pattern has been restructured as an assemblage of intensive variables, its dimensions, or coordinates. The apparatus' substratum is by now a vectorial field of connectedness itself composed of nested vectorial fields of connectedness. The speeds and rhythms of each element's variable structure and discrete dimensionality reciprocally define the apparatus while allowing for its continuity. As Deleuze writes (as quoted by DeLanda):

> Far from reducing the multiplicities' number of dimensions to two, the plane of consistency cuts across them all, intersects them in order to bring into coexistence any number of multiplicities, with any number of dimensions. (DeLanda, 2005, p.112)

Through such a "power of abstraction" an array of "genetic elements" has been obtained from Design Patterns, parameters that define important aspects of spatial behaviour. At the same time, each element construed as an individual process has been placed in continuous variation. As variables are wired to their respective Patterns, a set of Design Patterns becomes affiliated to each variable pointing to its affective capacity. At the same time, on this plane or field, spatial variables "can address each other and can be used by us to make claims, propositions, hypotheses, arguments" (Grosz, 2018, p.136). Through the abstraction process, the apparatus approaches materiality and materialised networks on the basis of continuity between the city's actual and possible entities, their properties, tendencies, and capacities (DeLanda, 2013, p.66). It articulates the city's complexity by intensively mapping its affective subspaces along with the patterns and thresholds of their behaviour. New cartographical maps offer a scaffolded approach to the city's most significant morphogenetic movements, those that drive its actualisation patterns.

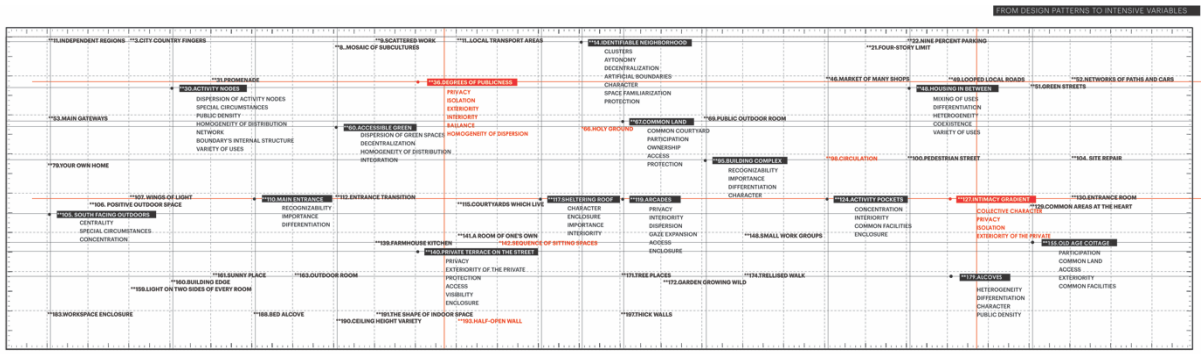

Figure 06. From Design Patterns to intensive variables (Passia Y. and Roupas P., 2021)

A Power of Creation: The Manifold's Architecture

To elaborate on how entities contribute to the becomings of one another, affording and constraining possibilities of movement and interaction, the manifold's

architecture is further designed. For this part, we shall rely on the *"power of creation*" capable of inventing ever-new relations between these differential or genetic elements" (Smith, 2012, p.218). In this framework, we articulate the *manifold's architecture* defined by the multiplicity and connectivity patterns of its local spaces or elements, the *intensive variables,* and the ways of connecting these spaces in an infinite number of ways. As Bennett points out, "matter has an inclination to make connections and form networks of relations with varying degrees of stability" (Bennet, 2004, p.354). The manifold's architecture establishes a system of communication between the elements of the multiplicity that until now have been non-communicating. Networked maps of the entities' mutual communication articulate their proximity and relatedness, as well as the "polydimensionality of their control mechanisms" (Galloway, 2007, p.67). Operationalising the extraction list, intensive variables interconnect on the basis of their affiliated Design Patterns as the manifold's connectionist structure is being gradually defined (Fig.07). The manifold's dynamic landscape consists of a nexus of communication patterns between its elements, mapped by means of networks of interconnected nodes.

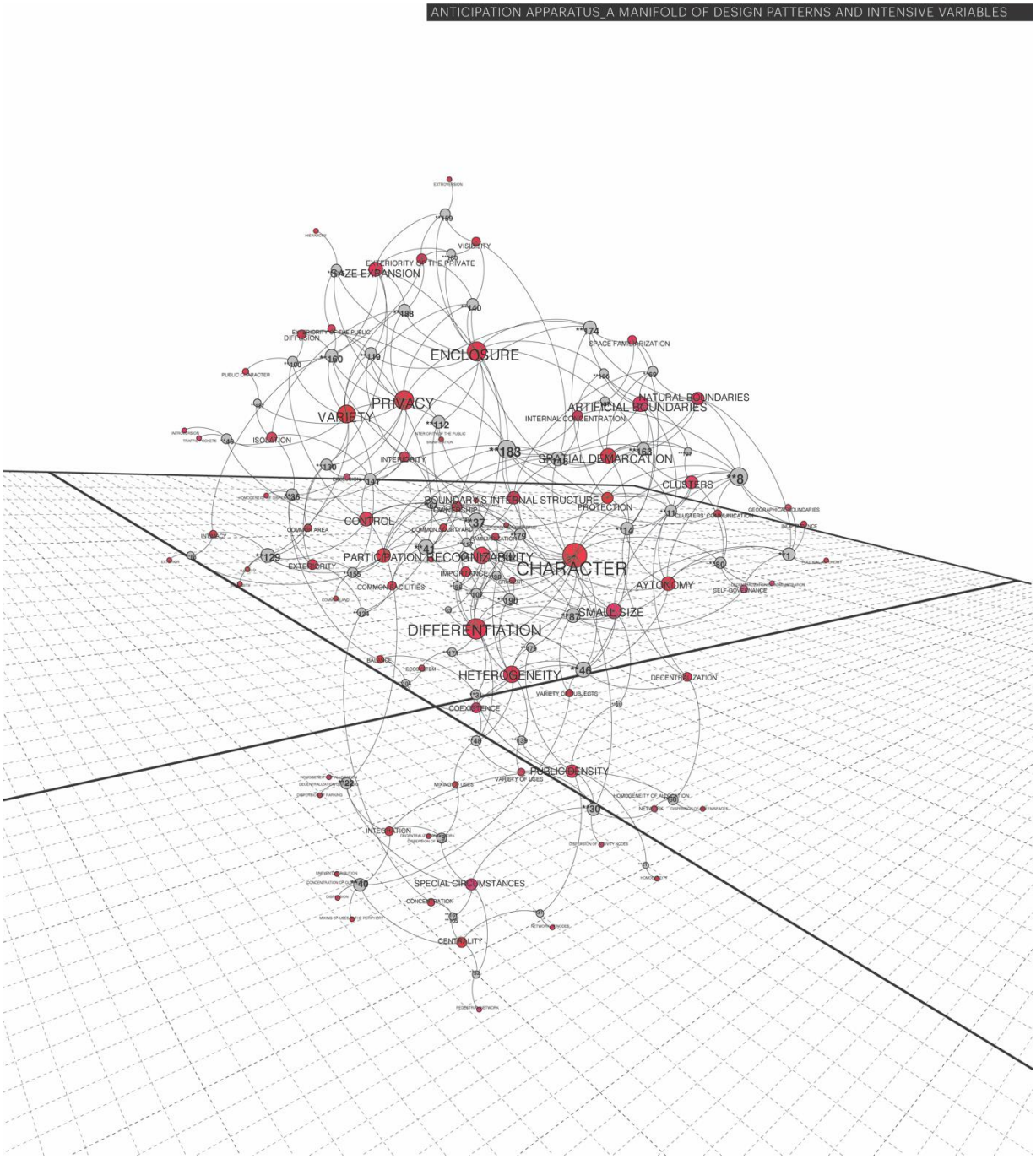

Figure 07. Anticipation apparatus_ A manifold of Design Patterns and intensive variables (Passia Y. and Roupas P., 2021)

Networks are controlled by protocols — the Design Patterns — and set the system's patterns of behaviour as well as the intensive boundaries where the system changes patterns, it's attractors and bifurcations respectively. The manifold's network topology consists of *nodes and connections*. Nodes are points or spaces in the manifold

representing its entities while connections are lines that relate any two such nodes with one another and define the entities' pattern of relation. Nodes and their patterns of connection constitute the manifold's form which in turn enables the manifold's function: "the speed by which certain elements flow from point to point, the kind of actions that networks find easier to perform" (Lury, Parisi and Terranova, 2012, p.19). In the apparatus, all active connections between entities are mediated by the Design Patterns, themselves nodal points on the topological surface. Nodes are multidimensional structures. They "by no means have contours that are defined once and for all but are chains of variables that are torn from each other" (Deleuze, 2007, p.343). *Connections* are fragile and precarious. As Deleuze, notes:

> "lines of different natures follow directions, trace processes that are always out of balance, that sometimes move closer together and sometimes farther away. Each line is broken, subject to changes in direction, bifurcating and forked, and subjected to derivations." (Deleuze, 2007, p.345)

The apparatus now resembles "a relational field of emergence" (Parisi, 2012) on which space is perceived as "assemblages of variables" and specific Design Patterns are correlated to its socio-spatial production processes. In the manifold's topological surface one can specify neighbourhoods of continuity, connectedness, and sameness in terms of fields of vectors and vectorial gradients **(**Lury, Parisi and Terranova, 2012, p.23) without having to use rigid lengths or metric quantities. The manifold's architecture establishes a system of communication between the elements of the multiplicity that until now have been non-communicating. What is of essence here are not the manifold's elements but what is between, a set of relations which are not separable from each other (Deleuze and Parnet, 1987, viii). This setting up of spaces in the manifold reintroduces the concepts of *continuity and qualitative properties* in articulating actual spaces and their possibility for change. Networked maps of the entities' mutual communication articulate their proximity and relatedness in structuring space.

Conclusion

The anticipation apparatus reconceptualizes the built environment as living continua in constant variation, mapping “objects that come into being, as they emerge from continuous and continuously varying fields of media-material and then dissolve again into those fields” (Sha, 2013, p.90). Through the apparatus, it is possible to explain how space changes in relation to networked patterns of communication between its elements, themselves variable entities. At the same time, it articulates *space as a field of connectedness composed of nested fields of connectedness* where change can be perceived as immanent and relational while space itself becomes fully intensive. Constructing new cartographies of diagrammatic connections of both existing and possible objects, the manifold is actively marking spatial and social continuities, similarities and connectivities. The concept of spatial assemblage is not only endowed with parameters — the city’s intensive variables — but now evolving as they interact with real-time data. The manifold becomes “a topological engine of potentialities”, a differential field of potential transformations that anticipates its affective becomings (Parisi, 2012, p.176).

Thinking and designing through topological media rejects traditional architectural objects, being propositional of how their staticity, irreversibility, and most importantly discontinuity can be overcome. Replacing actual spaces with the intensive variables responsible for their actualisation allows us to conceptually acknowledge those spaces as variable entities while at the same time mapping their capacities for sociospatial change. On the topological surface of the manifold, intensive variables of actual spaces are now able to communicate with other intensive variables, existing or possible, distant or proximal, “free or at least agnostic with respect to measure, metric, counting, finitude, formal logic, syntax, grammar, digitality, and computability, in short free of the formal structures that would put a cage over all of the lifeworld” (Sha, 2012, abstract). More importantly, as intensive spatial variables remain genetically connected to their respective Design Patterns on the manifold, it is possible to design concrete yet abstract actualisations. Thus, granting architectural objects their virtuality back even after the point of their actualisation.

The apparatus is operationalised for the design of ontologically unstable, intensive, and ecological spatial assemblages. Also, capitalising on the apparatus' continuity and connectivity, it has the ability to radically modify — multiply, intensify, diminish or invert — existing spatial assemblages, their components or their respective connections. In articulating the city's auto-generative dynamics, control has been replaced by an anticipation apparatus, a prediction machine that computes appearances and uncertainties via intensive pattern recognition, differential relations, and continual variations. An urban ecology of sociospatial continuities of forces and matter integrated into a single envelope: an intensive manifold whose existing and emergent neighbourhoods can be activated in any number of ways (Parisi, 2012, p.179). More than a merely aesthetic experience, the city is here understood and designed as the matrix of the topological forces that formulate it, its different actors coming into play, their territories constantly in the making.

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Japanese data strategies, global surveillance capitalism, and the "LINE problem"

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DOI: https://doi.org/10.1344/jnmr.v3i1.38966

Abstract

This paper situates data practices in Japan in a diffractive genealogy of surveillance capitalism. It puts data conceptualized in three ways into focus: real data, data in information banks, and data of the super app LINE. While technology embodying these concepts of data is mainly used in Asia, this technology is entangled with discourses and legislation in Europe and practices of U.S. American surveillance capitalism in important aspects. This article empirically traces these entanglements and demonstrates how discourses around data sovereignty, geopolitical shifts, historical background, global political and economic trends, and international policies intermingle in contemporary accounts of data and digital sovereignty in Japanese context. Decolonial theory is consulted in order to account for Japan's recent past as a non-Western territorial empire and the privileged position that Japanese experts on data have in the drafting of international data policies.

Keywords

Diffractive genealogy; Surveillance capitalism; Japan; geopolitics of data; Decolonial theory.

Introduction

The burgeoning field of new materialist informatics takes interest in the algorithmic condition, invoking Hannah Arendt's question of how to live an "active life" as the condition of possibility for politics (Arendt, 1958; Colman et al. 2018, p. 8). Arendt is also a central point of reference in Shoshana Zuboff's ground-breaking work *The Age of Surveillance Capitalism* (2018). (Re)constructing how practices of surveillance by giant tech companies like Google and Facebook have come to exert tremendous influence on our daily lives, she develops analytical terminology like the "behavioural surplus" and the "uncontract" that help account for the economic and political context of the said algorithmic condition and data practices. This paper aims to situate aspects of surveillance capitalism in Japan by performing a diffractive genealogy. That means it "materialize[s] ontological processes of formation at 'different scales'", "intra-actively and topologically (re)configur[ing] the genealogy" it produces (Mauthner, 2016, p. 265). The paper traces entanglements of data technology on the local, regional, and global scale, between the private and the public, as well as between empire and the economy of nation states. It draws on decolonial theory by highlighting an ambivalent position of Japan as both a recent imperial power, a global political agent, as well as a peripheral knowledge producer. The discourses, infrastructures and historical moments analysed in this paper are resonating with and being influenced by European and U.S.- American approaches to data sovereignty, privacy, and surveillance capitalism. The paper shows these resonances by analysing the cases of three types of data and the implications that arise. Overall, the goal of the paper is to draw a map that entails infrastructure, political actors, experts, nationalist/international/colonial-imperial discourses, and strategies, weaving these elements into a detailed narrative. This narrative, which is attentive to both geopolitical nuances and infrastructural materialities, performs a diffractive genealogy that contributes to a better understanding of data regimes and their interconnections with surveillance capitalism.

The structure of the paper is as follows. First, I present Zuboff's main points on surveillance capitalism and exemplify a shift towards data sovereignty in recent years as an important context for discussion of Japanese data strategies. Then, I discuss

the methodology and introduce two global designs (Mignolo, 2012) that have originated in Japan. The following main part of the paper, detects how three specific concepts of data – real data, data in information banks, and data of the super app LINE – come to matter in Japan and more generally. For this, concepts are regarded as specific material arrangements embodied in material-discursive apparatuses of production (Barad, 2007). While each of the three concepts is of interest in its own right, this paper pays special attention to the "LINE problem" as exemplary of geopolitical entanglements of data technology. The conclusion of the paper contextualizes the results more broadly.

Surveillance capitalism

In Shoshana Zuboff's account, surveillance capitalism was born at Google in the years after the burst of the dotcom bubble in 2000. User data had, until then, already been used for improving the quality of search results. But it also came to be used for better targeted advertising, opening a new economy of scale (Zuboff, 2018, pp. 96–99). New streams for the extraction of behavioural surplus were added incrementally, despite the occasional public outcry. This is congruent with Arendt's understanding that accumulation happens as part of a cycle, not merely because of a one-time explosion in the past that brought about capitalism (Zuboff, 2018, p. 124). Surveillance capitalism first spread to Facebook, then also to other giant tech companies like Microsoft; as they offer their services to smaller companies, surveillance capitalism now streamlines into many parts of our lives. Through the revelations by whistle-blower Edward Snowden in 2013, it became public knowledge that American intelligence agencies were complicit in this streamlining. That surveillance capitalism could emerge in the U.S. and that it is allowed to persist, is, importantly, due to "surveillance exceptionalism": the claim that the U.S. has no alternative but to continue its fight against terrorism after the attack on the World Trade Center on 11 September 2001. In order to fight "terrorist content", the sources for behavioural surplus are now also used to create algorithms that detect "radicalization" (Zuboff, 2018, pp. 448–449). Surveillance capitalists today provide stability for the political and economic order in many countries. For instance, at the height of the European migrant crisis in

2015, the German government urged Facebook to immediately draft a policy to protect migrants from hate speech. The company had to comply swiftly, skipping internal approval processes that would have taken months (York, 2021, pp. 19–20).

Reflecting fears of overreach from abroad – such as through U.S. surveillance activities and through Chinese economic espionage – has led to European countermeasures. With GAIA-X, the German government in October 2019 launched an initiative for developing a high-performance, competitive, secure, and trustworthy data infrastructure for Europe that enjoys strong support by the French government. In November 2019, it was reported that German chancellor Angela Merkel called for the EU to pursue “digital sovereignty”, especially through a reduction of the reliance on cloud services by Amazon, Microsoft, and Google (Chazan, 2019). As American and Chinese tech companies are part of the GAIA-X initiative, some argue that it “will neither undermine the hegemonic position of U.S. cloud services nor keep Chinese digital tech at bay” (Mayer, 2021, p. 3). Authors at American think tanks consider the rhetoric of digital sovereignty that accompanies the initiative as dangerous, as it could legitimate oppressive practices in countries that have less concern for human rights than the EU (Hillman, 2021, p. 225). Nonetheless, even though there are different terms for understanding sovereignty as it relates to data (Hummel et al., 2021), this discourse plays an important role in the concepts of data discused in this paper.

Observing data and its traces using Japanese-language sources

In agential realism, phenomena are understood to be sedimented out of the process of the world’s ongoing articulation, through which part of the world makes itself intelligible to some other part (Barad, 2007). Humans take part in the process of data coming to matter, and how they make sense of this process can be, at least partially, inferred from traces they leave. (Re)constructing a more or less coherent strategy concerning a concept of data over a certain time, then, can be done by identifying and interpreting relevant sources that contain such traces. As most of the sources I use are literature written by experts, it begs the question how to counteract an implicit replication of hegemonic discourses at least to some degree. For this, I take hints from decolonial theory.

Regarding the coloniality of power in general, the mainstream of decolonial literature still portrays the contemporary situation as "North Atlantic imperial states" opposing “China, Russia and Iran” as well as other “returning civilizations” (Mignolo & Walsh, 2018, pp. 6, 10). Besides not being North Atlantic, Japan, in this perspective, is in a precarious position, as it came to fulfil the “standard of civilization” already in the beginning of the twentieth century (Mignolo, 2012) but its dominant language, Japanese, *de facto* has only been of greater relevance for scientific knowledge production inside of Asia. As Eurocentrism is still prevalent in science, Japanese is not considered a language of scientific knowledge production, unlike English, French and German, which have been dominant languages in this regard since the Enlightenment (Mignolo, 2009). Even when pointing out strengths, specialists of the academic system in Japan might still call it an “invisible academy” with regards to an English-speaking audience (Cummings, 2015). Consequently, providing information on the affiliation of authors, institutional or otherwise, is key for interpreting textual sources in Japanese. Many of the authors quoted here are teaching at Japanese elite universities and are taking part in projects carried out in cooperation between the private and the public sectors. Their statements need to be scrutinized as such.

As Japan is a member of the Group of Seven (G7)[1], it has important agency in shaping international agreements on digital technology. The initiative *Data Free Flow with Trust* (DFFT) that aims to create legislative basis for the safe international flow of data was announced by Japanese Prime Minister Shinzō Abe at the World Economic Forum in January 2019. Originally progressing as an initiative of the very diverse Group of Twenty (G20) countries, it is now also on the data governance agenda of the G7 (Goodman, 2021). It is inherently concerned with limiting data sovereignty of nation states while naturalizing power differentials through the invocation of “trust” between parties of unequal power. The concept of the Society 5.0, a “people-centric super-smart society”, was introduced in the Fifth Science and Technology Basic Plan from 2016 and has gathered international attention for being broader in vision and giving

[1] The other G7 members are the U.S., United Kingdom, Canada, Germany, France and Italy.

more consideration to issues of sustainability than Germany's similar but older initiative Industrie 4.0 (Sołtysik-Piorunkiewicz & Zdonek, 2021). This is true especially in Southeast Asia, a region that is traditionally considered to be one of the most important markets for Japanese products and a major recipient of Japanese development aid. In the decolonial sense, both DFFT and Society 5.0 are very much global designs through which data practices in Japan exhibit coloniality.[2] Centering Japanese concepts of data, then, does not merely counterbalance a hegemonic Eurocentric perspective – a primary concern of Indigenous concepts (Smith, 2021) – but also aims to enable legitimate critique of these concepts.

Three concepts of data

While literature on imperialism through digital platforms has focused on U.S. platforms (e.g. Jin, 2015), China is now considered to be another important pole of colonial data power (Couldry & Mejias, 2019). However, each of the three concepts of data discussed below is traced back to the early 2010s, a time when the situation was different. Well into the 2000s, Japan was dominant regarding information technology in East Asia. Its post-war "economic miracle" was based on the entanglements with its former colonies in East Asia. Japan focused on private-public partnerships and on building "national champions", being a main driver of the diffusion of information technology throughout Asia (Cortada, 2012, p. 371). Referring to technology embodying concepts of data as "Japanese", then, signals that the dominant agency inside of sources is usually ascribed to Japanese persons or institutions. Thus, Japan's past as a territorial imperial power is still present in them, often in contradictory ways. A prime example for such a contradiction can be found in the identity of Son Masayoshi, founder and CEO of Softbank. Trying to hide his Korean heritage by using his Japanese family name Yasumoto in order to avoid discrimination

[2] "Global designs [...] are brewed [...] in the local histories of metropolitan countries; they are implemented, exported, and enacted differently in particular places" (Mignolo, 2012, p. 65).

in the past, he is now standing up against discrimination by openly carrying his old Korean family name Son (Ōnishi, 2019).[3]

Mobile phones already became widespread in Japan during the 1990s. With i-mode, the Japanese telephone company NTT in 1999 launched a mobile service platform that became a great commercial success inside of Japan and gathered enormous attention abroad. Although establishing i-mode in markets abroad was not successful in the long run, it laid the groundwork for the architecture of today's smartphones (Steinberg, 2019, pp. 127–128). Its model of offering services based on fees differed profoundly from the data- and advertisement-driven model of offering services "for free" prevalent in the Silicon Valley (Steinberg, 2020, p. 3). Notably, Google CEO Eric Schmidt openly told Natsuno Takeshi, one of the architects of i-mode, that he wanted to take the i-mode concept and extend it to the world (Steinberg, 2019, p. 130). What made a difference was that Google knew how to make use of the behavioural surplus using the data extracted with its operating system Android and the Google Play Store, achieving global scale and succeeding in markets where NTT had not. It was during the 2010s that the i-mode-based phones finally gave way to Android and Apple's iOS smartphones in Japan, too.

It is from a position of former strength and the acute feeling of having fallen behind that most of Japan's current expert discourse and drafting of data policy takes place. However, privacy is given significant consideration; this has increased since the General Data Protection Regulation (GDPR) became effective in the EU in May 2018 (Zuboff, 2018) and Japan's data protection legal regime was judged as adequate by the European Commission in January 2019. Increased efforts for harmonization over many years had preceded this (Van Overstraeten, 2020, pp. 138–139). Thus, the data strategies in Japan (re)constructed below have been entangled with the growing concern for data protection that developed especially in Europe.

3 Not only is Softbank today one of the major Japanese technology companies, it also maintains the world's largest technology-focused venture capital fund.

Real data

The term "real data" (*riaru dēta*) points to a particular type of big data and features in many strategic documents, including those concerning Society 5.0. Its importance is sometimes justified as arising from traditional strengths of companies in Japan. Current business literature connects real data to the practice of continuous improvement, *kaizen*.[4] An article in the bimonthly magazine of the Ministry of Economy, Trade and Industry (METI) from 2016 mentions real data, *kaizen*, and a newly established AI research laboratory by Toyota in the Silicon Valley (Keizai Sangyōshō, 2016b). In the same issue, real data is highlighted as a keyword of interest and defined as:

> Health information, movement data, operation data of factory equipment (and so on), the data gathered by sensors (and so on) from activities of individuals, companies and nature in the real world.[5] (Keizai Sangyōshō, 2016a, p. 24)

In March 2014, Morikawa Hiroyuki, professor at the Research Centre for Advanced Science and Technology of the University of Tokyo, is interviewed in a publication by Hitachi; he explains that the data of "giant corporations who are the winners of the current IT world" have been gathered through the internet and constitute "virtual data". However, he holds that in sensor-intensive environments with machine-to-machine communication like factories, Japan has an advantage because there is much more data in such a setting. The key to using real data lies in having people go into the field (*fīrudo*) and have them discover tasks which they can solve, a setting which is "the polar opposite" of the setting where people write code "at their table" (Hitachi, Ltd., 2014). The title of the article ("On the frontier (*furontīa*) of 'real data', there is a chance for Japan to win") uses a metaphor known among system architects in the United States: the Internet of Things (IoT) is as inevitable as the drive to the West on the American frontier (Zuboff, 2018, p. 260). For Morikawa, Japanese can excel in settings where real data is relevant because teamwork is necessary. In contrast to the

[4] Gathering data for making continuous improvements to the production process, a practice that has come to be known globally under the term *kaizen* (Japanese for "improvement") has been central to the Toyota production system.

[5] *Kenkō jōhō, sōkō dēta, kōjō setsubi no kadō dēta nado, kojin kigyō shizen no jissekai de no katsudō ni suite sensā nado ni yori shutoku sareru dēta.* Here and elsewhere all translations from Japanese are mine.

"individualism of Europe and America", the "cultural soil of Japan" that encompasses organizational strength and the "Japanese spirit" (*wa no seishin*) is very advantageous to this (Hitachi Ltd., 2014). In his 2019 book titled *Data Driven Economy*, Morikawa explains that the value is won through "mutual cooperation of the real world and the cyberspace": collecting data, analysing the data, and going back "into the real world" (Morikawa, 2019, p. 5) – the core aspect of *kaizen*. In this way, the amount of real data is "by far [such that] it cannot be gathered by single corporations like Google or Amazon"[6] (Morikawa, 2019, p. 39). This is why the internet, smartphones, the cloud and sensors should function as infrastructure (Morikawa, 2019, p. 8). Claiming that certain big data is gathered in the real world while other big data is gathered in the virtual world may seem arbitrary but is relevant from a performative viewpoint.

By referring to real data, initiatives of American tech companies have been confronted from a position of (perceived) Japanese advantage. At a meeting of the governmental Intellectual Property Strategy Headquarters in late 2019, Alphabet's Sidewalk Toronto is referred to as a project abroad gathering real data. Concerning the anxieties regarding privacy that Alphabet was met with (see also Zuboff, 2018, p. 267), the slide points out that the Japanese government has launched the Global Smart City Alliance together with the World Economic Forum and the G20 (Naikaku-fu Chiteki Zaisan Senryaku Suishin Jimukyoku, 2019, p. 13). Kitsuregawa Masaru, Director General of the National Institute of Informatics and Professor at the Institute of Industrial Science of the University of Tokyo, in that meeting heuristically explains that in cyber-physical systems (CPS), if cyber refers to a digital platform, then the physical refers to real data; moreover, "CPS + real big data" in his interpretation is the 5.0 in Society 5.0 (Naikaku-fu Chiteki Zaisan Honbu Kōsō Iinkai (Dainikai), 2019, p. 13). At a conference on big data in medicine, Kitsuregawa frames "real big data" a "source for business" and emphasizes that papers and patents are not sufficient anymore to effectively make use of research results in the private sector. He holds that the "design of data is key" and that Japan should be as proactive as Germany is with GAIA-X, displaying a screenshot of the above-cited article (Chazan, 2019) on a slide (Nihon Iryō Kenkyū

[6] *Totemo Gūguru issha, Amazon issha de atsumeru koto wa dekinai.*

Kaihatsu Kikō Kōshiki Channeru, 2020). Kitsuregawa thus refers to data sovereignty in two understandings, one pertaining to the context of IT architecture and one pertaining to the context of research (Hummel et al., 2021, p. 12).

The concept of real data has proved to be productive enough to feature in the name of a prominent international project. Sompo Holdings, a company traditionally focusing on insurance, in 2019 set up a joint venture with the American data analysis company Palantir; the companies are now deploying a "Real Data Platform for Security, Health, and Wellbeing" (Business Wire, 2021). As Palantir has been engaged in predictive policing in the U.S. (Zuboff, 2018, p. 451), real data is relevant to a new materialist perspective on surveillance capitalism beyond Japanese context.

3.2. Information banks

"Information banks" (*jōhō ginkō*; also called Trusted Personal Data Management Services, TPDMS) are institutions that facilitate the usage of personal data in the Japanese economy. The naming reflects that their business model is similar to that of traditional financial institutions: An individual user can decide to deposit data to a trusted entity, an information bank, which in turn will provide the data to a third party; a portion of the economic gain is then returned to the individual user.[7] In the available sources, the concept can be traced back at least until 2009 to a group around Shibasaki Ryōsuke, professor at the School of Engineering and director of the Center for Spatial Information Science at the University of Tokyo (Sakimura, 2018). A presentation at a TEDx event in Tokyo by Shibasaki from 2012 highlights potential uses for personalized medicine (TEDx, 2012). Research by Shibasaki and a group around Sunahara Hideki, professor at the Media Design Lab at Keio University, in the years that followed focuses on the necessity of anonymization, privacy and incentives for users to share data. On the relevance of the system, Sunahara in 2019 has made

[7] For a detailed English-language explanation of the information bank system including its relation to the international MyData movement, see (Sakimura, 2020).

the judgement that “IoT security and the information banks are the foundation of the society that considers the internet a precondition” (Ōta, 2019).

Business-oriented literature now only rarely mentions these roots. The book *MyData economy: Personalization and the information banks* sets out to answer how “our lives” (*wareware no seikatsu*) will change through the birth of the MyData economy, an “economic sphere” that makes use of personal data through information banks (Sasaki, Haruyama, & Shida, 2020, pp. 2–3). While not overly prominent, the book also explains how information banks are connected to the international movement MyData on controllability of data that has been the topic of studies on data activism (e.g., Lehtiniemi & Haapoja, 2020). It was through the yearly conferences of MyData since 2016 that the system became known abroad. One of the regular participants from Japan reports that while the information bank system was, in the beginning, met with scepticism – questioning whether it had become “alienated/estranged” (*kairi*) to the “spirit” (*seishin*) of MyData – it has come to be recognized as a “third way”, differing both from the “European system” and from the “American system”. He had the impression that finally, the adoption of a more fine-grained approach in handling approval – from comprehensive agreement to “using individual agreements at its base” (*kobetsu dōi bēsu*) – brought the information bank system closer to MyData’s “vision” (Sasaki et al., 2020, pp. 167–168). A guidebook on how to make use of the information bank system makes clear that this shift happened before the background of the movement to impose stricter regulations on the protection of private information in Europe and U.S. (Morita, 2020, p. 39). As the review process of the adequacy of personal information protection in Japan – the Japanese Act on the Protection of Personal Information had been revised in 2015 – by the EU lasted between 2016 and 2018 (Van Overstraeten, 2020, p. 139), such modifications in data strategies during this time were certainly not limited to the information banks.

In an edited volume on Society 5.0, Shibasaki et al. (2020) give the diagnosis that the information bank system has met difficulties because the leaking of personal information cannot be undone. Credit scores are a more advanced remuneration scheme than merely receiving coupons or information that is deemed to be useful; however, that credit scores have been met with some hesitancy in Japan is seen as

another reason for the slow progress of the information bank system (Nomura Sōgō Kenkyūjo, 2020, pp. 196–198). Still, an article in a research journal published by the Ministry of Internal Affairs and Communications concludes that while the unwanted emergence of a uniform “social credit score” like that envisioned in China poses the biggest problem (see also Zuboff, 2018, pp. 451–458), there is no general argument against certain credit scores on the grounds of discrimination (Ohya, 2019).

Its limited success up to now notwithstanding, the system remains relevant. Ishii Kaori, professor at the Faculty for Global Informatics of Chuo University and one of the editors of the international journal “Global Privacy Law Review”, in the economy-focused newspaper Nihon Keizai Shinbun in December 2020 refers to the information bank system as an issue of improving competitiveness in the digital economy. Focusing on aspects of privacy legislation and private initiatives in several countries (EU, U.K., U.S., Australia, Japan, and China), she judges that except for China, there is an international trend towards data portability that could enable users to fight the dominance of American tech companies. Describing the progress of the information bank system as “sluggish” (*teichō*) – until then, one company had received regular certification and four companies had received a more elementary certification – she emphasizes that “groping for an answer” (*mosaku*) on how to increase the mobility of data with multiple approaches globally is necessary. Asset management through the information bank system enables individuals to act as players in the market for data usage (Ishii, 2020). Making clear that information banks would not be limited to users in Japan, the authors of “MyData economy” emphasize the relevance of DFFT in the “Asian region” (*Ajia chiiki*) (Sasaki et al., 2020, p. 202). Multiple governments of those countries are, however, currently drafting data localization requirements for at least some industries. The situation is still not completely clear and has to be monitored, as the Japanese-language journal “Business Legal Affairs” informs in October 2021 (Murata, 2021, p. 48). The assertiveness of post-colonial states through legislation in this regard reflects an understanding of data sovereignty that is relevant to Indigenous peoples in former territorial empires (Hummel et al., 2021, p. 12). Notably, although much research on Society 5.0 outside of Japan has been carried out at Indonesian institutions (Shahidan, Latiff, & Wahab, 2021, pp. 97–98), it was Indonesia (alongside

India and South Africa) that had opted out of DFFT negotiations among the G20 countries in 2019 (Goodman 2021).

Emphasizing the role of "privacy tech" more generally, Tanaka Michiaki, professor at the Business School of Rikkyo University, is sceptical about the current state of the information bank system and emphasizes that one should make use of the data in a "customer-centric" fashion (Data Insight Henshūbu, 2020). Using the right approach, Japan could become the third pole (*daisankyoku*) in the world regarding the building of smart cities, the other two being North America and China – a striking divergence from the positioning of Japan inside of the MyData initiative, where the other two points of reference are Europe and North America. In addition to Toyota, it is importantly Softbank that Tanaka considers key in this (Tanaka, 2020, p. 219). However, given that Softbank has access to large pools of personal data including those of several payment and bonus point systems (Yamashita, 2021), this could enable the comprehensive profiling of users and establish Softbank as a powerful surveillance capitalist.

Softbank is currently also one of the owners of LINE, a messaging app attached to an ecosystem which is becoming part of Japan's critical digital infrastructure.

Super app data

With the functionality of instant messaging, the app LINE can be used on smart phones worldwide. However, inside of Japan, LINE functions as a platform for other platforms and offers many features, including food delivery, online shopping, music streaming (Steinberg, 2019, p. 218) and more recently also mobile payment. In 2020, it was the dominant messaging app in Japan, Taiwan and Thailand, the second-most widespread in Indonesia after WhatsApp (Nihon Keizai Shinbunsha, 2020) and had shares in the South Korean, Malaysian and Mexican markets (Steinberg, 2020, p. 4). Its feature-richness and market dominance can be compared to that of WeChat in China and KakaoTalk in Korea; these three super apps have profited from regional scale through a co-evolution of their ecosystems (Steinberg, 2019, pp. 229–233). However, contrary to WeChat being created by the Chinese company Tencent and KakaoTalk by Korean company Daum, LINE was not created by a Japanese company.

Rather, it was created by the Korean company Naver, whose chat app for Korea did not turn out to be successful.

According to an early narrative supported by the company, LINE was created and launched immediately after the Great Tōhoku Earthquake on 11 March 2011, which was followed by a catastrophic tsunami and an accident at the Fukushima Daiichi Nuclear Power Plant. Amidst the disaster, the mobile network in Japan suffered an overload and people had to communicate with their families using low bandwidth, data-based communication tools like Twitter, which LINE wanted to provide in a better and more straightforward way. Closer scrutiny shows that NHN Japan, the Japanese Naver subsidiary, had been developing the app (launched in June 2011) already before the earthquake (Steinberg, 2020, p. 4). A retrospective on the history of the internet during the Heisei era (1989-2019) by public broadcaster NHK in 2019 explains that the app had been under development before the earthquake but makes no reference to the company being owned by Korean Naver (NHK "Heisei netto shi (kari)" shuzai han, 2021, pp. 155–161). The company could publicly present LINE as a Japanese app within Japan, while it was considered a Korean app in Korea; a more accurate description would have been that it was a collaborative project between Japanese and Korean engineers and designers, influenced by both the i-mode model of platform building and the KakaoTalk chat app (Steinberg, 2020, p. 4). According to the Nihon Keizai Shinbun, it is only very recently that LINE acquired the financial power to "fight for the leadership in Asia's IT market"[8]: a merger of Naver-owned LINE with Softbank-owned Z Holdings was announced in 2020 (Nihon Keizai Shinbunsha, 2020). The merger was carried out on 1 March 2021; the two CEOs emphasized that they wanted to pursue the "local route" (*rōkaru rosen*) in the Asian market, "hiring local engineers with a focus on Southeast Asia"[9] (Nihon Keizai Shinbunsha, 2021a). While potential for growth on a regional scale is reduced, this strategy makes sense under requirements of data localization.

[8] *Ajia no IT shijō no shudōken arasoi*
[9] *Tōnan Ajia o chūshin ni enjinia no genchi saiyō*

That issues of geopolitics are relevant to data came to broad attention in Japan when the "LINE problem" (*LINE mondai*) suddenly became a topic in the Japanese mass media. On 17 March 2021, many newspapers reported that Chinese engineers involved in the development of LINE were able to view personal information of Japanese users. A front-page article in the evening edition of the Nihon Keizai Shinbun informs that at the "related company" (*kanren kaisha*) LINE Digital Technology Shanghai, four employees could access data of users whose data is stored inside of Japan, including their names and telephone numbers. Regarding the messaging feature "talk", they could access dialog and pictures, whose content was reported as inappropriate. Regarding this, the company LINE stated that the related company was involved in the development of a gaming platform and had been granted access rights in the scope that is necessary for this, and that no inappropriate access has been verified. The article also mentions that LINE had already submitted a report to the "government's Personal Information Protection Commission" (*seifu no Kojin Jōhō Hogo Iinkai*) (Nihon Keizai Shinbunsha, 2021b).

The Ministry of Internal Affairs and Communications stopped the services it offered over LINE on 19 March, and other national ministries as well as municipal governments followed over the next days. This included the service to make appointments for vaccination against COVID-19, something that LINE facilitated in coordination with the respective governments. It was also reported that data concerning LINE's payment system and health services had been stored on servers in South Korea. Beginning on 20 March, the Chinese National Intelligence Law was regularly problematized in articles referring to the LINE problem; Article 7 of the law that had been passed already in 2017 stipulates that "any organization or citizen shall support, assist, and cooperate with state intelligence work" (Tanner, 2017). In a press conference on 23 March, LINE emphasized that it had been relocating data to Japanese servers already since February 2021 and that this process will be completed soon (Nihon Keizai Shinbunsha, 2021c). Those who saw the LINE problem as a phenomenon of being critically reliant on the former colony Korea may have experienced a moment of Derridean hauntology of Japan's imperial past (on this notion in agential realism, see Barad, 2010). Some critique also targeted Softbank –

for many on the far right a dog whistle to denigrate the Korean heritage of its founder Son Masayoshi.

Experts on data in Japan seemed less concerned about the LINE problem. The timing of the reporting was hardly coincidental: exactly for 17 March 2021, the Cabinet Committee of the Japanese House of Representatives had scheduled a debate on the establishment of a Digital Agency (*Dejitaru Chō*) and on drafts of several laws relevant to information technology, including the “Basic Act on the Formation of a Digital Society”. The incident concerning LINE was already paid attention during the debate; Hirai Takuya, then Japanese Minister for Digital Affairs, stated that he had confirmed that there were reports on this matter in the newspapers that morning, but that no detailed information is available yet – and in any case, according to Hirai, it was an issue for the Personal Information Protection Commission. He emphasized that it was an administrative body independent of ministries (*sanjō iinkai*) that is able to “firmly/properly” (*shikkari*) handle the protection of personal information (Kokuritsu Kokkai Toshokan, 2021, txt/120404889X00920210317/77). The following day, the committee continued the debate. As an expert witness, the specialist on data protection law Ishii Kaori (see previous section on information banks) in her first statement gave an assessment regarding the harmonization of privacy law and the responsibilities that should decide how to proceed further with legislation. When pressed on the LINE problem later in the debate, she judged that while the issue concerned accountability and the scope of assent, it was a problem that could likely be dealt using the current legislation (*hōsei*) on data protection or at least using the usual procedures, in such a way that the Personal Information Protection Commission can exercise its supervision authority (Kokuritsu Kokkai Toshokan, 2021, txt/120404889X01020210318/6, 26). Kokuryō Jirō, a key figure in creating the Japanese platform theory behind the i-mode business model (Steinberg, 2019, pp. 109–110) who is now Professor at the Faculty of Policy Management and the Graduate School of Media and Governance of Keio University, on 23 March through Twitter gave his opinion on the problem. Among other things, he warned that a Japan-only (*hinomaru kanketsu*) strategy would be the “path to defeat” (*haisen e no michi*) and that instead DFFT should be concretized. Rather than focusing on access,

business models that structurally betray trust (*kōzōteki ni shintaku o uragiru*) should be problematized. Moreover, a "witch hunt" would be dangerous (Kokuryō, 2021). The perspective Kokuryō takes tends to limit the room for data sovereignty pursued by nation states.

The question why the problem gathered much public attention while experts did not see the need for changes in legislation arises as a matter of course. A hint is provided in an interview with Amari Akira, member of the Japanese House of Peers and then head of the Parliamentary Alliance for Rulemaking and Strategy of the ruling Liberal Democratic Party, published in the online Huffington Post on 9 April 2021. Amari says that security has to receive more consideration, but that it would be "short-circuited" for Japanese companies to end business relations with China. He calls LINE's approach, which includes being preemptive in raising security standards beyond what is currently dictated by law, a "template" for other companies that handle personal information. "It may sound weird, but I think it [noticing the LINE problem; H.K.] was good. It exposed that Japan cannot read the air";[10] "it does not take missiles to put down Japan" (*Nihon korosu nya misairu iranu*). In the case that technology and information shared by the U.S. with Japan leaked to China, there is the danger that Japan would be "decoupled" (*dekappuringu*) from the U.S. along with China (Takahashi, 2021). Implicit in this is the common assumption that a substantially worsening relation to the U.S. would threaten the national security of Japan.

While the wording is drastic, Amari's concern for the diplomatic environment was well-founded according to the account given in "American-Chinese confrontation" (*Beichū tairitsu*), a book published in July 2021 by Sahashi Ryō, associate professor at the International Relations Institute for Advanced Studies on Asia of the University of Tokyo. According to Sahashi, the haphazard politics of the government of U.S. president Donald Trump in confronting China had provoked negative reactions and suspicion among many allies in the preceding years – giving them a reason to pursue data sovereignty, it could be added for the interest of this paper. But the government

[10] In cultural anthropology, "reading the air" (*kūki o yomu*) is interpreted as the Japanese practice of adjusting one's actions to the expectations of the surrounding.

of the new U.S. president Joe Biden, inaugurated on 20 January 2021, by March had made it clear it would further pursue or even strengthen the confrontation, this time with a believable commitment to human rights and democracy (Sahashi, 2021, p. 270). The approach to include allies in the confrontation succeeded to the degree that the U.S., the U.K., Canada, and the EU imposed parallel sanctions on several officials involved in the oppression of the Uighur Muslim population in the Chinese province of Xinjiang by 22 March (Wintour, 2021). While Japan did not possess a law appropriate for acting similarly, multi-party initiatives of members in the National Diet that already existed gained attention and further support (Nemoto, 2021).[11] In May 2021, the European Parliament formally froze the ratification process of the planned Comprehensive Agreement on Investment between the EU and China as some of the Chinese counter-sanctions targeted its members (Sahashi, 2021, p. 218).

When the U.S. government of Donald Trump threatened to ban the app TikTok on the grounds of the Chinese National Intelligence Law posing a danger, an editorial in the centrist Japanese newspaper Mainichi Shinbun from September 2020 considered pointing to the law a mere "excuse" (*kōjitsu*) to interfere in business activities of a company (Mainichi Shinbunsha, 2020). However, an editorial in the same newspaper from 24 March 2021 clearly warns about dangers arising from the law. It also cites LINE CEO Idezawa Takeshi admitting that the company had missed a "change in the tide" (*shiome no henka*) (Mainichi Shinbunsha, 2021). Thus, the LINE problem emerging as a topic of interest in Japanese mass media points to a perceived shift in the geopolitics of data, one that experts on data had, nevertheless, been aware of.

Conclusion

This paper has (re)constructed three different data strategies by performing diffractive genealogy and geopolitical mapping of the data strategies and discourses in Japanese context, with the decolonial perspective in mind. While the technique of border thinking (Anzaldúa, 1987; Mignolo, 2012) is not easily applicable due to Japan's recent imperial past, the fact that Japanese is not a dominant language in science

[11] On the deployment of surveillance technology in Xinjiang, see (Chan, 2018).

necessitates narrative innovations in order to account for the (relatively) strong agency that Japanese experts *de facto* have in influencing international policy regarding data. This hints towards and supports epistemic disobedience – delinking from the illusion of the zero-point epistemology (Mignolo, 2009) – that is inherent to Baradian onto-epistemology and appropriate to problematize surveillance capitalism more generally.

From the position of former strength and a prominent access to institutions like the G7 and the World Economic Forum, Japan tries to shape international policy according to the (perceived) interests of its information technology industry. Judging by the development of the data strategies analysed, it is often the hesitance of users in Japan and a drive towards data sovereignty in Southeast Asia that hinder a broad adoption of data technology developed in Japan. Future adoption could arise if people in Japan and abroad develop and maintain trust in institutions like the Personal Information Protection Commission. If a global "race to the bottom" regarding privacy expectations takes place and surveillance capitalism is accepted wholeheartedly, the consideration that privacy does in fact receive in this technology would turn out to be detrimental or meaningless at best. However, as data technology developed in Japan is entangled with Europe in important aspects of legislation and discourse as well as with practices of U.S. American surveillance capitalists, the underlying concepts are of interest for a more livable and sustainable future in Japan, Asia, and beyond.

To conclude, the three concepts of data are significant in understanding data naturecultures (Haraway, 2003) in the context of global surveillance capitalism and data sovereignty. While the concept of real data is entangled with more general techno-nationalist narratives in Japan, it can enrich debates on the ownership of data and point to the situated infrastructures and discourses that affect data practices. The data practices related to information bank system point to an interesting example of an ambiguous case of data management that, depending on implementation and discourses, can both support surveillance capitalism as well as counter it by providing a "third way" to address data sovereignty that depends less on the structure of nation states and large corporations. The data practices established through the LINE app and the "LINE problem" show how geopolitical considerations as well as histories of

imperialism and colonialism emerge to haunt (in a Derridean sense) contemporary data debates, material practices, and data policies. That this problem could gather substantial attention is, importantly, because the coloniality underpinning data practices in China had become apparent and because the confrontation between the U.S. and China was judged to become a long-term issue. As these geopolitical conditions keep shifting, this paper hopefully shows that drawing genealogies of data practices from differently situated geographic, political, and historical contexts will remain an important tool for new materialist informatics methodologies.

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Algorithmic Kinning

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DOI: https://doi.org/ 10.1344/jnmr.v3i1.38962

Algorithmic kinning is a term that invites us to think about the role of intelligent machines in kin-making practices and the processes of kinning performed by algorithmic technologies.

In her work Donna Haraway proposes that kin-making[1], and specifically the non-genealogical understanding of it, is a political exercise in building affinities and structures of sustainable getting-along: "living and dying well with each other" (Haraway, 2016). Haraway establishes and explores her bonds with OncoMouse (Haraway, 1996), the cyborg (Haraway, 1991), and the fissure isotope Plutonium-239 (Haraway, 1996), postulating them not along the classical line of social contract theory, but rather by sharing a sense of agency and material intimate interconnections through complex shared histories. Such kinships are inherently technological. This technological aspect is highlighted in the work of Kim TallBear, an Indigenous scholar whose work Haraway references extensively in her own research. TallBear focuses on the technologies of DNA testing in determining membership and belonging to indigenous tribes (2013). She points out that DNA testing technologies are not neutral in their rendering of kinship, but rather play a structuring role in promoting the narrative of tribal belonging as racialized. Such narrative and the use of DNA testing for establishing kinship, according to her, does not account for the impure ways of belonging that are much more than blood and involve adoptive kin-making, belonging to particular land and its history, as well as political autonomy and authority.

[1] "Kinning" is a made-up verb referring to practices of kin-making that has been used both in scholarship that builds on Haraway's own work and non-academic contexts. The latter include, for instance, the concept of "kinning" that describes roleplaying or identifying with a fictional character (see https://www.quora.com/What-is-kinning - accessed on 18.02.2022) I am grateful to Sam Skinner for pointing out these non-academic uses of the term.

Relationships, however, are not made exclusively by humans. Media and cultural theorist Wendy Chun highlights that in the contemporary digital realm, especially (but not exclusively) social media and other social spaces that rely on algorithmic infrastructure, relationships are made and unmade based on “homophily” or likeness (Chun, 2018). In other words, our digital interactions, powered by algorithmic technologies, are structured through patterns of sameness – a kind of “birds of a feather flock together” logic. This is not purely a social concept, even though it originated in sociology (ibid.) – it is an algorithmic principle that structures interactions and makes predictions that are then incorporated into algorithmic decision making. This can be seen clearly not only in “relationship factories” such as Facebook and the filter bubbles of likeness that they generate, but also exemplified in phenomena such as the Cambridge Analytica scandal that revealed how algorithmic structures perform categorizations and filiations that are beyond the control of those who are placed in such structures (Hern, 2018). Thus if traditional, genealogical kinship ideas are postulated on the slogan that blood is thicker than water, then the digital infrastructures that we rely on and the “hypernaturecultures” that these infrastructures create, begs the question: is data thicker than blood?

Data analysis and modelling with digital tools is nothing new: computational biology and genetic sequencing are good examples of relatively established technologies. However, it is not only biological matter that is structured by algorithms – biological models algorithmically structure contemporary technocultures as well. Scholars such as Sarah Robinson and Pat Treusch explore the algorithms that are based on biological models. Robisnon (2016) investigates an algorithm that adopts the principle of quorum sensing in cell-to-cell communication to mimic the rules of interaction between cells in order to model the interaction of data within digital environments and information flows. Treusch (2017) looks into CLONALG algorithm that replicates immunological principles. Deep learning structures in machine learning – neural networks, – too, turn to biology in search for data processing models by aiming to re-produce the model of neuronal interaction in the neocortex of the human brain (Lee et al., 2016). Deep learning systems, which build layers of artificial digital neurons requiring large computing power, are now used in projects such as “deep genomics” to trace genetic patterns of illness and develop new medicine (“Deep learning for genomics,” 2019).

"Pattern recognition" and "categorisation" are key concepts that help understand the basic logic of algorithmic systems: machine learning algorithms discover patterns and group data points into clusters or predict which category a certain element of data will fall into. Patterning is by now so widespread in its use as to have become infrastructural, thus making participation in patterns intrinsic to the use of digital technology, not optional. Machine learning algorithms sieve through immense amounts of data pertaining to humans and non-humans alike. They perform processes of sorting and categorisation, discovering filiations and (re)configuring relations. From genes to sexuality, from biological matter to news, machines not only learn but also produce new knowledge that is operationalized and sedimented into further infrastructures, to be mined again.

In such contemporary techno-nature-cultural predicaments, kinning has to be re-thought to include algorithmic kinning. Haraway's notion of kinning is a passionate call to adjust our ways of worlding and relating. However, if such kinning is about "staying close to strangeness", as she writes (Haraway, 2016), then we are in trouble because our technologies create and embody worldings that are based on familiarity and existing injustices (Benjamin, 2018). Thus the provocation that algorithmic kinning brings is to ask: who and what has the agency in performing the kin-making? Who and what has a say when it comes to belonging, in the context where such belongings are produced and reproduced algorithmically? What are the effects of such kinning and how can kinning retain an element of being in proximity to the strange and the alien? (Klumbyte, 2018) Algorithmic kinning is not by default a foreclosure of agency, but rather a call to "kinnovate" (Clarke & Haraway, 2018) with/in computational infrastructures away from homophilic filiations and towards multispecies justice.

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Stoniness

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DOI: https://doi.org/10.1344/jnmr.v3i1.38964

Data technologies consist of minerals, of metals, and of other natural materials. Their origin is thus the stone and they are therefore fundamentally geological. We process stones and put them under electricity in order to comprehend the world and rock-hard realities around us. Stones that calculate are at the centre of the problem-solving strategies of the complex issues of the present. With the term “stones that calculate,” we mean the assemblage of all data processing devices or infrastructures and their socio- political impact on our automated society. From smartphones, Internet cables to data centres, we look at the material complexity, cycles, and dependencies it takes to provide the enormous data and energy resources needed for our daily Netflix consumption, climate models and algorithmic governance. No need to emphasise here that approximately 5% of all greenhouse gas emissions come from the maintenance of digital technology (Royal Society, 2020).

We propose the category of stoniness to make visible the connections between ecology, power, and information technology. In order to structure our extended notion of stones, we developed a research archive of resources that maps academic and artistic perspectives that reflect digital conditions within materialist discourses (https://stones.computer). Under the label of post-digital materiality, we combine historical classifications, critical analyses, and speculative interventions from both established voices as well as young researchers. We examine the research field on the basis of three material dimensions. We start with the actual material conditions of digital infrastructures – asking what is a stone? We then scale up to questions of power and geopolitics of the digital – asking where is the stone? In the last step, we

look at moments of corporeality in the seemingly dematerialised digital space – asking who holds the stone?

Material of the digital

The focus here is particularly on the material consequences of digitisation. In contrast to supposed dematerialisation narratives (cyberspace, cloud, or wireless), we are interested in the extended cycles of digital ecologies. We follow neomaterialistic media theories that can be seen, in a rough summary, as the intensive excavation of where (and when) the materiality of media actually is (Parikka, 2015; Peters, 2015; Jue, 2020). In the sense of opening the black box, this focus looks at the resources needed to keep a planetary-scale computation going. In addition to new spatial orders, altered temporal relations become apparent. By combining these enhanced ideas of scale, we are also dealing with different notions of the Earth itself: like the globe, the terrestrial and the planetary (Likavčan, 2019).

Power and geopolitics within the digital

The second pillar focuses specifically on geopolitical arrangements in the post-digital space. The term “post" here signifies going beyond digital mystifications and naturalisations. Hence, the often-hidden infrastructures of digital systems are revealed and rearranged in the overall complex. We are interested in new emerging data landscapes as well as legal and ethical perspectives and issues relating to data, with useful suggestions coming from the discussions around the Technosphere (Amoore, 2020). We draw upon geopolitical theories that are capable of framing the complexities of planetary-scale computation, such as Benjamin Brattons "The Stack“ (Bratton, 2016).

Bodies of the digital

The third pillar combines approaches concerning the conditions of production and consumption rendered by platforms and services of our daily usage. The focus is on the concept of labour and exploitation of the human body. The discussion is nourished, for example, by notions of embodiment and feminist theories (Plant, 1997). The complex relationship of dependence between human self-perception and

technical devices, in the sense of techno-intimacy or moments of identification, are also examined (Picard, 1997).

Overall, the notion of stoniness we are proposing not only makes visible the material entanglements of our contemporary human condition, but it also actively helps to position stones as main tool to navigate human thinking. It is through the electrification of stones that we have been able to better understand our history and the ecological complexities surrounding us. Stones shaped our perception as much as we shaped stones (Colomina and Wigley, 2017). Now it is up to us to calibrate our view on them.

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MATTER Journal of New Materialist Research

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Contagious Education

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DOI: https://doi.org/10.1344/jnmr.v3i1.38965

Abstract

The use of data to govern education is increasingly supported by the use of knowledge-based technologies, including algorithms, artificial intelligence (AI), and tracking technologies. Rather than accepting these technologies as possibilities to improve, reform, or more efficiently practice education, this intra-view discusses how these technologies portend possibilities to escape education. The intra-view revolves around Luciana Parisi's idea of "digital contagions" and participants muse about the contagious opportunities to escape the biopolitical, colonial, and historical rationalities that contemporary education now uses to govern populations in ways that are automated, modulated, and wearable.

Keywords

Data; Governance; Sensors; Biopolitics; Decolonization.

Introduction

The following intra-view was developed in the Fall of 2021. The intra-view brings together Drs. P. Taylor Webb (TW), Marcelina Piotrowski (MP), and Petra Mikulan (PM) to reflect upon their symposium entitled *Contagious Life and Education's Erratic Encounters with Informatics*, presented during the New Materialist Informatics conference, 24 March 2021. The symposium used Luciana Parisi's (2007, 2013) idea of "contagion" to examine the transmogrifying aspects of informatics and data in education. The conversation is guided by three questions designed to provide participants ways to reflect upon their symposium, their respective research programmes, and additional insights into their innovative and exciting work.

During the symposium on 24 March 2021, Drs. Webb, Piotrowski, and Mikulan discussed how digital data resist representations, and instead, assume "a life of their own." The symposium examined the contagions of data in relation to the ways education is governed – and in relation to the ways that education governs subjects – through biopolitics, ecology and wearable sensors, and as a speculative site of decolonization concerned with datafications of race and ethnicity.

The symposium discussed education governance as accelerating processes that increase forms of control through the contingent practices of decidedly non-human and contagious silicon-based objects. The symposium illustrated these ideas by discussing the ways planetary life is increasingly sensed through wearable informatics at the level of the biological (e.g., wearable sensors). The symposium concluded with a speculative reading of life as excess contagion, which provides intensifying forms of biopolitical control and corresponding modes of becoming between human and inhuman networks.

Intraview

MP: How are you currently thinking with/about informatics and new materialism in education?

TW: My research examines forms of educational governance and is designed to better understand how education is constituted through expressions of power, force, and politics. In this sense, my research examines the practices and conceptions of educational politics and policy. I am also interested in the converse of this arrangement. That is, my research also examines how the practices and policies of education govern, rationalize, and produce particular subjects within liberal, neoliberal, and advanced liberal (authoritarian populist) architectures. As a result, my research is designed to be both empirical and speculative, and designed to examine relationships between competing subjectivities, political economies / control societies, and biopolitics. Currently, I am examining how Artificial Intelligence (AI) influences educational governance, particularly in relation to the global practices of what Nicolas Rose (1991) discussed as "governing by numbers." I link these non-human forms of governance to ideas of "new materialism" through Coole and Frost (2010), particularly their discussion of the "bios": bioethics and biopolitics. My work has always emphasized ontology, and I appreciated that Coole and Frost (2010) also emphasized ontological concerns in their conception of new materialism and biopolitics. In terms of informatics, Petra and I were fortunate to spend a year learning about neuroscience at the University of British Columbia as part of her postdoctoral research. As a result, we began thinking about bioinformatics, AI, governance, and biopolitics. We have a chapter coming out shortly that examines the potential for bioinformatics to escape and decolonize forms of biopolitical control produced through education (Webb & Mikulan, 2022).

MP: My research focuses on environmental media, digital culture, and posthumanism, and their relation to epistemology and ontology, particularly in the contexts of projects aiming to facilitate public environmental education. I have been focusing on the implications of non-human sentience on speculative planetary futures facilitated through uses of sensor-produced data in public knowledge projects. For me, public knowledge projects and adult education aimed at ecological change will increasingly need to contend with the concurrent cybernetization of Earth and of bodies and this is where informatics and matter intersect in my own work. The story of how planetary informatics are producing knowledge about life at the level of the biological (e.g., personalized smog sensors) is a key part of my current research. The horizon of

environmental education is becoming detached from the idea of human symbolism, interpretation, and transformative approaches through wearable sensor technologies. I agree with Taylor that "governing by numbers" is central for understanding contemporary intersections of informatics and biopolitics. For example, while the quest to represent environmental crisis to affect education and action has been a central way to think about and between matter, climate change, and education, the shift to planetary informatics that autonomously alter conditions of life are significant ruptures in ecological thought. I am examining public knowledge projects from innovation design and sensor technology companies that are challenging the idea that ecological thought can incessantly be human.

PM: As Taylor mentioned, we are working on a speculative approach to the not yet imagined possibles afforded by the potential that bioinformatics portends for escaping and decolonizing forms of educational and bioethical control. I am drawn to both Claire Colebrook (2019) and Denise Ferreira da Silva (2014) in terms of decolonial thinking of informatics, matter, and materiality. Their feminist poethics helped us think about different scales of extension and intensity simultaneously (desiring, cosmic, organic, historic, quantic, informatic). My research with Nathalie Sinclair has understood simultaneous extensions and intensities of informatics, matter, and materiality through what we call a stratigraphic "method." My work with Nathalie has morphed into a study of time and temporalities as governing expressions and governing practices of colonial atavistic-juridico-economic power that suspend all thought of "educational revolution," rupture, and refusal in the field of education. As such, my research examines personal and impersonal questions of what it is or is not to be human presently, and in relation to the many people that have been living dystopic futures for too long now. My research examines the roles of education to anticipate and address our increasingly artificial and non-human modes of existence. My own sense is that humans have always been artificial despite the loud clamour about humanism, and, for me, our particular moment of informatics and materiality only illustrates, reaffirms, and extends our artificiality, and in particular ways. As result, my research examines possible futures involved with either sustaining formalized education, like schools and universities, and their modes of colonial, organic, and biopolitical operation and extraction at all cost, or to escape and terminate education

as we know it. Taylor and I just published a short editorial about this very wager, and several students have told us that the idea of "escaping education" is very important to them (Webb & Mikulan, 2021). In this sense, my work is motivated by Whitehead and his terrific idea that, "[a]ny serious fundamental change in the intellectual outlook of human society must necessarily be followed by an educational revolution" (1929, p. 116). I definitely feel that this quote captures our moment perfectly.

TW: That is a fantastic quote. Whitehead's *The Aims of Education* is one of my favourite books! I think your and Nathalie's idea about stratigraphic method is a potent way to understand simultaneity. I would be remiss if I didn't mention Dr. Liz de Freitas. Liz is someone I really enjoy, and her work has been super helpful to how I conceive some of the relationships of informatics, new materialism, and education.

MP: Why is Luciana Parisi's (2013) idea of "contagion" an important/timely topic or approach when it comes to looking at materiality of informatics in education?

TW: For me, Parisi's discussion of contagion portends a "dangerous politics" that I believe might provide opportunities to escape neoliberal educational governance. Parisi locates contagion as the ways algorithms prehend or sense the very architectures that they have been scripted into. As such, contagion signifies how an algorithm's "own" sense of data ultimately transforms both the data itself and the architectures (i.e., hardware and software) that provide the meaning of those data. Contagion, then, signifies thresholds of control between humans and the non-human machines, but also signifies a densification, "gridification," or, to borrow from Deleuze and Guattari, a striation of control as we devise more and more ways to govern and control populations through sophisticated technologies. Facial recognition technologies and software would be an example in education. Deleuze (1992) presciently discussed control and technology in his essay "Postscript on the Societies of Control." In that essay, Deleuze argued that one way to escape technological control is to actively "jam" infrastructure systems. He gives the example of distributing computer viruses through various electronic networks. Parisi's idea of contagion, I believe, provides a similar idea but one that is resolutely non-human. In other words, contagion articulates a decidedly non-human approach to jamming technological systems, which, albeit a speculative approach, provides opportunities for political

action within technology's own fallibilities, leakages, and contagions. As education control becomes increasingly dependent on practices of numerical governance and automation, I am looking for ways to help people elude, flee, and decolonize education through the cracks and crevices produced in technological governance. Contagion is an idea that I like quite a bit for these purposes.

PM: Taylor gives an excellent interpretation of contagion when he speaks to algorithm's potentiality, or the non-reducibility to either data or its architectures. Contagion in this precise sense implies new standards for what counts as authentic knowledge about life, thought, and technological control. For my research purposes, I extend Parisi's idea of contagion with Colebrook's (2019) idea that "all life is artificial life." For Colebrook, if we do not focus on logics that sustain ourselves as organisms conditioned on, and directed towards, autopoiesis, "we" might begin framing different questions regarding what life and living are, and what it might portend and do outside organic self-enclosures. Like Parisi's idea of contagion, Colebrook's provocation helps me to think life in terms not reducible to processes of self-maintenance, production and reproduction.

MP: I agree. Parisi's (2007, 2013) contagion is an important concept that functions methodologically to investigate the virality of irreversible ruptures caused by autonomous technology. In Parisi's case, this refers to mutations and excesses produced through artificial intelligence. For me, it is about the possibility of producing space apart from the totalizing ideas that haunt public knowledge projects under the guise of education and democratization at a time of planetary catastrophe, and this is where my work intersects with Taylor's. This is pertinent in terms of ideas about how "knowledge" is perceived to be central to ontology. It is not clear "who" "knows" and whether anything can be known at all when we talk about the data produced through sensor technologies that have their own non-human experiences of things like climate change, smog, radio frequencies, and pesticides. Sensor technology has its own bionic tendencies, which Parisi (2009) also discusses.

PM: I completely agree as well. Working with both ideas of contagion and artificiality helps me think about non-human modes and expressions of relating and non-relating and the repercussions these ideas have for education. As such, I locate a certain

romantic anxiety in the field of education where these "contagious" principles and standards of automation, algorithms and AI that now govern life, information, knowledge, education, and humanity might diminish the human experience as "we" know it. Like Marcelina, I am very interested in the crises produced for education concerning questions about "who knows" and "knowledge." These kinds of questions radically reorient and undermine how formalized education understands individual, classed and social comportments to life, living, and wellbeing. Accounting for the contagious architecture of (artificial) life in pedagogical terms, wherein local loss and perishing are the necessary events for any potentiality or "new" mode of possibles to take place, might provide us with a new ethos and pathos in approaching the wager that education might need, to use Taylor's words, "jam" the already known and presupposed scales of technological control and educational architectures. In other words, contagion provokes a profoundly pedagogical idea of refusing educationally established and colonial provisions (Bignall and Patton, 2010). Contagion bifurcates logics about organisms and organismic life into either living and dying, but perhaps more interestingly, zombie or artificial modes and expressions determined in advance, and usually only in terms of organic and already actualized (distributed to/for some and not others) enclosures.

TW: It is so fun to work with both of you. The crises of epistemology – that is the "who" or "what" of knowing – including the very crises of "knowing" and "knowledge" – is something that really threatens, as Petra noted, education and many of its romantic tropes. Most epistemologies privilege ideas of discursive "knowledge," which is not a good metaphor for understanding our embodied, contagious, artificial, and sensored-thought. Embodied, contagious, and artificial sensibilities are, instead, ways to displace knowing and knowledge for ideas of thought, thinking, prehension and so on.

MP: Such a neat conversation. The question, for me, then focuses on what this does to educational theory when the very idea of thought is opened up to its outside allowing itself to become infected with machines that have sensations? We can see this in others' work recently as well. Beier and Wallin (2020) have recently called this the "heretical elaboration of an outside thought" (p. 54). Contagion is a timely methodology to not only think about stagnation in humanist theories about human relationships to the material world, but also describes some of the mutations that have

already been imbedded in the sensation of being produced as a being by smart Earth technology. It is very much about deterritorialization at every turn.

TW: This is an excellent point, Marcelina. Deterritorialization is great way to focus on thought and thinking rather than "knowing" and "knowledge." Deterritorialization reminds me to follow the territorializing forces that produce knowledge, which, in turn, territorialize or enact "knowing" subjects.

PM: All your work touches on matter, informatics, and education in different ways and yet has the common theme of excess. How do excess and matter work in your own research on education/informatics?

TW: Excess is, again, another way for me to think about the politics involved with escaping control. I'm influenced by John Law (2004) and his ideas of excess. He discusses excess in ontological terms, and in ways that work with the overwhelming flux of the real. He locates excess within a politics of alterity, and in ways that are designed to intervene in representational epistemologies that reduce political action (for example, many research methodologies). As such, I find several similarities between ideas of excess and Parisi's idea of contagion. In my current research, algorithms and AI become the non-human "other" that are used to develop intensifying forms of control. Nevertheless, they contain within their own design and architectures non-representational forms of contagion, artificiality, and excess. As a result, the global-financial rush to develop AI will inevitably and simultaneously proliferate forms of algorithmic excess and contagion, providing possibilities for increased political action for more and more people. Excess, then, is a kind of methodological axiom I use to identify flux, leakages, and contagions, and in ways that "jam" systems and / or provide viral flows for escape (e.g., computer virus). For Law, excess is intimately connected to method, which I appreciate as someone employed as a researcher, but also as something to think with and through, e.g., excess as tactical, strategic, and fluid.

MP: My approach to inquiry has been by way of "more-than-"…, and here I am referring to concepts like more-than-representational (e.g., Thrift, 2008), more-than-rational (Anderson, 2006), and more-than-human (e.g., Manning, 2010). This approach has

emerged from a concern about reductivist methodologies that do not register ambiguity and excess. Thrift (2008) for instance focused on the excesses that are produced in new arrangements between bodies, power, technology practices. Data production, which is central to informatics, is excessive because it produces rather than represents, and the notion of data excess as that which sentient machines produce to keep human bodies alive complicates the porosity of data/bodies' insides/outsides.

PM: I understand excess in its ironic force. When thinking about the politics and ethics involved in escaping different forms of control and governance in education, expressions and styles of relating deemed artificial, parasitic, contagious and necrotic are relegated, governed and surveyed as negative modes of existence. At the same time, as Jason Wallin and I try to show (forthcoming), these very negative modes of existence function as support and signifier of that which is simultaneously enacted and rejected by the real. The negative operates ironically within the field of education as an excess (or in Jason's words, "the horror of the noumenal Real").

MP: Interestingly, data excess about Earth, produced by non-human sentience, will produce contagions that have unintended effects. My research examines some of the ways contagions of sensor data will manifest. For instance, for some it may result in AI enabled datafication of what Joanna Zylinska (2021) has called ruin porn, or alternatively in beliefs in data democratization (Hong, 2020). Both signal ideas of technological exit (e.g., Sharma, 2020) caused by affective excesses in their own ways. My interest is in how such exit fantasies are produced through informatic/matter contagions, and contagions are also always prompting me to ask new questions about ontology.

PM: Algorithmic contagions provoke, in my mind, new possibles and these will continue to infect and abduct the existing material fabulations and virtual potentialities in education. Taylor and I have been working on this idea that if bioinformatics can simultaneously equalize and aggravate unequal forms of life, accelerating this bioinformatic moment might, ironically, instantiate a "decoloniality of informatics" precisely through the proliferation of the negative, i.e., contagious, uncertain, errant, necrotic, and mutant life modes, expressions, and styles. We suggest

elsewhere (2022) that rather than reform education's anti / racist declarations of vitalist life, we suggest an accelerated use of "contagious bioinformatics" as a way to proliferate unknown possibles.

TW: Thanks you two. Always fun to work with both of you.

Acknowledgments

Marcelina Piotrowski's research is supported in part by funding from the Social Sciences and Humanities Research Council.

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MATTER Journal of New Materialist Research

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Speculative Materialities, Indigenous Worldings and Decolonial Futures in Computing & Design

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DOI: https://doi.org/10.1344/jnmr.v3i1.38967

Abstract

This intra-view follows a round-table discussion that took place during the New Materialist Informatics conference on 25 March 2021. The discussants – Indigenous researcher and game designer Outi Laiti, artists and researchers Luiza Prado de O. Martins, Femke Snelting and Caroline Ward – start with their own artistic, academic, and creative practices and discuss how these practices relate to otherwise-worldings in computing that engage materialist, anti-racist, decolonial, Indigenous, and trans*feminist thinking and doing. This discussion, facilitated by artist Ren Loren Britton and researcher Goda Klumbytė, brings up questions of collaboration and infrastructures needed to support otherwise practices in computing and design.

Keywords

Otherwise computing; Indigenous games; Artistic research; Black feminist epistemologies; Social justice; Decolonial practice; Speculative methodologies.

Introduction

Critical computing is emerging as a branch of informatics that takes up the Indigenous, decolonial, feminist concerns within computing. It is both critical of existing modes of doing informatics, as well as active in transforming engagements and doing informatics differently. This work crosses disciplinary boundaries and performs research and design oftentimes in a diffractive manner, bringing different fields of scholarship to bear on each other. This means that methodologically critical computing research and design do not rely only on computational practice to generate insights into computing but take multiple points of entry and different material forms to critique and work with "otherwise computing practices"[1].

Importantly, critical computing and critical design praxis start from positions that are overlooked or marginalized in conventional computing and aim at actualizing re-orientations. These re-orientations and critical investigations often focus on legacies of colonialism, heteropatriarchy, racism and other structures of oppression, and question how they get enfolded in objects and categories of analysis, and how they prescribe certain values and ways of seeing (Mills, 2018). Critical re-orientations scrutinize and challenge white prototypicality (Browne, 2015) that gets inscribed at multiple levels, from the sourcing of minerals for technologies, to designing machine vision, to generating forms of representation that enact racializing assemblages (Dixon-Román et al., 2019; Weheliye, 2014).

At the same time, new conceptual and praxis horizons are being opened. Speculative design, for instance, is by now an established method and domain of research. Indigenous AI as a field is also gaining ground (Abdilla et al., 2020), as are eco-centered, anti-extractivist perspectives in computing and design (Escobar, 2018; Kannabiran, 2014; Overdorf et al. 2018). The role of researcher and designer is crucial in this. How do we find forms that move us towards de-centralization, de-individualization, while resisting techno-nationalism? How do we foster material forms of accountability towards computing and worlding otherwise? These critical practices expose and aim to find ways around, above, through and out of contemporary technological, computational infrastructures that foreclose experiment

[1] For instance, see a series of entries on "otherwise practices" within computing on the Engines of Difference blog: https://enginesofdifference.org/2021/01/04/otherwise-practices-with-in-computing/ (accessed on 17.02.2022).

and speculation by optimizing for profit. At stake is the becoming of technology and becoming of techno-life-worlds. We invited Indigenous researcher and game designer Outi Laiti (OL), artists and researchers Luiza Prado de O. Martins (LP), Femke Snelting (FS) and Caroline Ward (CW) to talk about their practices in critical computing and design. The discussion was facilitated by researcher Goda Klumbytė (GK) and artist Ren Loren Britton (RLB).

Intraview

GK: So Ren and I would like to ask you all to first talk about your own praxis and propositions for re-orientations that engender otherwise worlds with computing.

CW: I would like to share some early thoughts on collaborative practice around AI justice as an example of ways of thinking about computing otherwise, through different forms such as collectivity, time beyond the human lifespan, and Black feminist thought. My practice intersects across design, art and social research and I am currently on a fellowship, together with Dr Erinma Ochu, to address racial justice and AI ethics with JUST AI[2]. Having a joint fellowship and being part of a fellowship cohort allows us to realise that thinking and action happen in collaboration – in this case, a lab in which racial justice and AI ethics can be considered.

Within the lab we have centred Black feminist epistemologies to think through AI justice issues whilst developing our individual projects. This space[3] is held as a queer, anti-racist, anti-ableist space produced at the intersections of our lived experiences and expertise. Through opening up our lab to the broader discourses on AI ethics, we are forced to confront the power dynamics and culture that come with mainstream investment and interest in minoritized collective thought. Particularly in the field of AI, which is dominated by colonial rules of extraction of value, knowledge and profit, while also reinscribing what knowledge, bodies, information and facts are deemed "valid." This labour of extraction reinforces what Patricia Hill Collins describes as the matrix of domination (Hill Collins, 1991). Rather than challenging or overcoming cycles of inequality, technical fixes – such as AI – too often reinforce and even deepen the

[2] See https://www.adalovelaceinstitute.org/just-ai/ (accessed on 17.02.2022)
[3] https://bit.ly/JustAIOpenLabs (accessed on 17.02.2022)

status quo around racial codes that are born from the goal of and facilitate social control (Benjamin, 2019) and serve whiteness through epistemically reproducing it (Katz, 2020).

How then to escape the matrix of domination, or are all minoritized efforts likely to become co-opted or complicit? Care as power may be an option. Black feminist epistemologies centre lived experience at the intersections of race and gender with dialogue built around the ethics of caring (Hill Collins, 1991). By centring Black epistemologies within our work and within my design practice and the narratives that we tell I am considering how an effect of care creates collective power and justice and reorganizing around collective liberation.

In our Just AI fellowship, we start by connecting AI to questions of care. Specifically, we want to think about care that extends with and beyond the human. We are doing that by thinking with three oak saplings that we started growing.

Figure 1: Preparing the acorns for incubation in a damp, cold environment.

These saplings at some point will demand more time, space and light than we can currently give them. We wonder if perhaps this offers propositions for collective consciousness and equitable living in a warming world where there is inequitable access to land, shade and air quality. We are coming to value local, community-based experiments, the tools and technologies for the possibility to sustain and replenish life. Our practice is based on inscribing alternative narratives for equitable

futures and taking thinking with more-than-humans seriously while doing that. Here we are in solidarity and acknowledge Indigenous knowledge systems and practices.

LP: In my work the question of collective effort is also important, particularly with regards to decolonial work in design and multispecies justice. In my recent practices I have been thinking with and through environmental disasters that have been consuming the South American continent (forest fires, pesticide spillages, among others). The history of coloniality is profoundly marked by an impulse to consume; a perpetual and insatiable hunger for profit that is used to justify all kinds of injustices and abuses to human and non-human persons. In satiating this hunger, the modern/colonial project classifies not only non-human bodies — of land or water, for instance — but also *human bodies* under the definition of "resources," thus excluding these from every possibility of subjectivity. Indeed, the indigenous author and activist Ailton Krenak points out that when we remove the personhood from the river, the mountain, when we remove their senses, thinking that this is an exclusively human attribute, we allow these places to become residues of extractivist industrial activity (2019, p. 38). For some to be satiated, others must be plagued with scarcity—in the form of environmental degradation, the breakdown of food systems, conflict, and forced migration, among others.

We are then tasked with answering, through our everyday practices, difficult questions: how do we create the conditions for life whilst navigating a system meant to produce death? How do we reject this framework of scarcity and consumption? How do we sustain practices that centre on care and affect through decolonizing work? When considering these questions, I often turn to the words of the Zapatista indigenous liberation movement in Mexico. In their Fourth Declaration from the Lacandona Jungle, they argue for the creation of a "world where many other worlds fit." In this pluriversal conception, abundance and generosity act as governing principles that allow communities to reject the universalist impulses of coloniality. In their words:

> Many words are walked in the world. Many worlds are made. Many worlds make us. There are words and worlds that are lies and injustices. There are words and worlds that are truthful and true. We make truthful worlds. We are made by truthful words. In the world of the powerful there is space only for the big and

> their servants. In the world we want there is space for all. The world we want is a world where many worlds fit. The nation we build is one that may fit all the peoples and their languages, that may be walked by all gaits, that may be laughed in, that may be awoken. (Comité Clandestino Revolucionario Indígena-Comandancia General del Ejército Zapatista de Liberación Nacional, 1996, n.p.)

Decolonization is not an individual choice; it demands collective, sustained, committed work.

OL: I approach the questions of otherwise practices in computing through Indigenous perspective, where the story begins with the land. Indigenous worldview is about relationality, especially with the land, including all the ways of knowing, the systems of arranging information, entire cultures, ways of conceptualizing the world, languages, history, and everything is nurtured by the ties between Indigenous peoples and the land.

As an example, this game, *Rievssat* made at the Sami Game Jam in 2018, describes the story of land connections and oppression from the Indigenous Sámi perspective. Sami Game Jam's goal was to, in a short span of time, produce video games based on Sámi culture. It had 44 participants from around the world, some of them being local Sámi. The event took place in the northernmost municipality of Finland, Utsjoki.

Figure 2: Screen grab from the game *Rievssat*. Picture source https://itch.io/jam/sami-game-jam/rate/228170 (accessed on 18.02.2022), copyright team Rievssat.

The bird in the game *Rievssat* is willow grouse. It is flying through the eight seasons of Sámi year, trying to find food in a world that is constantly changing. Suddenly there are human markings increasing rapidly, and the bird struggles more, season by season. This is one of the six games created through collaboration and sharing, highlighting the Indigenous land connection. These games show that Sámi game development is a cultural attribute that emerges when given space. Combining technical skills with cultural insight generated knowledge based on sharing, where intangible knowledge combined with technical skills produces tangible outcomes like video games. Sámi game developers also saw the game development event as a possible platform for building reconciliation, which, in and of itself, is telling of the collective experience and its potential.

Digital games play an empowering role in Sámi culture as a platform for self-determination supporting both the traditional game and play tradition and preserving and developing the Sámi's intangible cultural heritage. The cultural games developed from within the Sámi culture serve to normalise mundane Sáminess, rather than to promote cultural symbols or underscore the fact that they are games based on Sámi culture. When the Sámi make games for themselves, they do not have to underscore the importance of cultural objects or situations and are free to instead focus on the deeper thematic levels at, for instance, the emotional level. When that happens, the games can truly express something genuine: current, everyday cultural content without the pressure to please outsiders.

FS: An example that I want to bring to the table has to do with otherwise computing practices that are rooted in trans*feminist critique and artistic practice. It is based on the book *Volumetric Regimes: Material Cultures of Quantified Presence* that I have edited together with co-researcher and companion Jara Rocha, where we present "disobedient action research," triggered by concerns about the way 3D computing seems to quite routinely render sexist, ableist, speciest and ageist worlds. We call it the Industrial Continuum of 3D. It can be observed when volumetric techniques and technologies flow between industries such as biomedical imaging, wildlife conservation, border patrolling and Hollywood computer graphics. Its fluency is based on an intricate paradox: even if the continuum smoothly moves between distinct, different, or mutually exclusive fields of application, it leaves very little space for

radical experiments and surprise combinations. It thrives on fabricating similarities between situations, invoking a type of space-time that is both fast and ubiquitous, ignoring complexity and implications. But volumetric computation can and should operate otherwise.

Connecting to what Luiza mentioned on pluriversality, I think that if we want to find another computational "how" that will not negate nor erase other modes of existence, our first task is to rescue the desire for "continuity" from the claws of the established, the normed and the Modern. Against the unbearable persistence of 3D, discontinuity, latency and un-settlement are evident counterforces only as long as they engage with resisting that which 3D settles by flow: neoliberal accumulation, colonial commercial normativity and one-directionality.

So we compiled a list of trans*feminist proposals for "computing 3D otherwise." Here I want to just briefly list three examples. First example: Remediating Cartesian Anxiety. What if we decide to use six instead of four axes, twelve instead of three or zero instead of n? What if we take time to get used to multiple paradigms for orientation, instead of settling for only one regime? Letting go of the finite coordinates of x, y, z and t could be a first step to break with the convenient reductions of parallel and perpendicular assumptions.

Second example: Extra-planar Projections. We know that the cartographies of complexity are already there, but we just have been lacking the means for their representation, their analysis, and their use. Extra-planar projections would not assume the axioms of linearity, but rather convoke playful articulations that diffract inwards. 2.1D, 2.5.3D and 2.999999D.

Third example: Fits-and-Starts-Volumetrics instead of smooth continuity. Time as mattered through computation works too hard on appearing continuous. How to hold time beyond constant speed, agile advancement, and smooth gait? Linear time is a problematic norm that will always confirm and appreciate what goes forward. Let's use our energy for flowing with what gets crooked and throttled, to move with the flutters and stutterings.

In case these proposals feel too hard or even impossible to implement, remember that this is always the effect of hegemony! Because abolishing the Industrial Continuum

of 3D means to place it at the eccentric core of a kind of computing that dares to world without patriarcho-capitalist and colonial structures holding it up.

GK: There are a lot of resonances between all your practices: questions around the importance of collaboration, strategies of resistance that sustain multiplicity, but most of all the search also for alternative ways to *think and do* through and with computing and design.

FS: Yes, I would like to pick up on this *doing* and ask Caroline: could you describe how do you approach such enormous questions of trying to claim for AI justice in the daily life of the lab?

CW: It starts in centering care and actively working to create a care-full anti-ableist, anti-racist space already in the way we bring up those questions – of justice, of AI practices and how they relate to justice. For instance, we, the fellows in the AI Justice programme, put a lot of effort in holding a certain kind of space for each other. One of the first things we do when we come together is ask how we are and check in with each other. We create a space to vent and to bring our frustrations. This can be heavy sometimes but also crucial to have a space to off-load and bring experiences that we can learn from and grow as a collective.

But I have a question for everyone too: how are your collaborations made possible, perhaps virtually and otherwise? And I am interested in the resistance to being co-opted. As our labour continues and is opened up to share with dominant AI communities, we are considering how to avoid the trap of becoming complicit, co-opted or erased through practice. Is collective resistance the only possibility for change towards different possible futures?

OL: I guess in our work with Sámi game jams, collaboration – including outside of Indigenous community – is important because we don't have enough knowledge for the game developing tools at the moment within our community. However, collaboration is also a really powerful tool. The Indigenous people saw that collaboration was moving things forward and they thought it would be, for example, a tool for reconciliation. But of course, there are many questions how it's done so that it supports Indigenous communities and does not create more sense of otherness or reproduce power structures.

LP: I can also comment on collaboration and the intricacies of framing collaborations. In 2019, I was working on a project called The Councils of the Pluriversal. For this, I was collaborating with a group of indigenous artists based in Boa Vista, in Northen Brazil, in the Amazon basin, and in Rio de Janeiro, my hometown. In my initial idea, the Councils would be a way to convene artists, curators, singers, storytellers, activists, who were conducting their own versions of or thinking about pluriversality and were involved in the struggle for decolonization. As I lived and worked with others in the Jaider Esbell Gallery in Boa Vista, I realized that I didn't need to be there as a mediator for anything, I didn't need to convene anything – I just needed to offer my own perspective as a layer, and not a framing. Resisting framing, especially the idea of a universal frame of reference – which is what is at the core of colonialism, but also at what Femke called the "Industrial Continuum of 3D" and what Caroline referred to as the matrix of domination in Hill Collins' work – is at the heart of the idea of pluriversality. It goes against the universalist impulse of sameness.

FS: To me this also connects to the tension between the probable and the possible, which manifests a lot in computing as well. Between what looks like a range of possibilities, a flow of abundance, as Luiza would say, but that in fact is confirming the probable – that which is optimized according to the logics of colonial capitalism. How to not let go of computation as such, but at the same time, not to get drawn into the probable disguised as the possible is the hard work that I think we all in our own ways and in our own spaces are trying to do.

CW: In terms of multiplicity and plurality, I've always found Spinoza and Braidotti (e.g. 2019) are quite useful and productive in thinking around the "and... and... and" instead of "either – or", and that we don't know what a body – human or technological – can do[4].

RLB: Outi, is multiplicity or the idea of pluriverse also something that your work on Sámi games resonates with?

OL: I think it's a hard work sustaining pluriverses. For me the key is how to avoid self-colonization, especially in spaces of collaboration. When we collaborate, we are

[4] The logic of "and... and... and" is initially discussed by Deleuze and Guattari in *A Thousand Plateaus* (2014, pp. 25, 98, 99), even though I think of it more explicitly in the context of Braidotti's work. Thank you to Jacqueline Barreiro for pointing out this initial reference.

mixing and mashing different epistemologies and ways of seeing the world. This can make it hard to hold your space at the same time. However, collaboration and support are sorely needed. This support can be anything, from supporting Indigenous game developing events financially, to organizing digital tool workshops and sharing tool knowledge or collaborations. Research plays an essential role of making the voices heard, but the most important lesson to be learned is sovereignty. The change happens from the inside, guided by Indigenous worldview. We have our own path that we are trying to walk on. And then there's the main road next to it, where we can deepen the knowledge of, for example, game development tools. But the collaboration goes between these two worlds. We are not building bridges, we are walking side by side, but we are taking on our own roads. That's the balancing act – how to walk alongside without getting pulled to the main road.

RLB: Thank you, Outi, that's beautifully put. I think that brings our intra-view to a close. As a final note, I would like to highlight that all your work and the topics we discussed also point to the importance of embodiment – physical embodiment, but also forms of technological embodiment and embodiment of different worlds through alternatives. These alternatives also need infrastructures of support for otherwise practices in computing that are oriented towards multispecies, pluriversal, decolonial, anti-ableist, trans*feminist presents and futures to flourish. I look forward to the ways in which we continue to build and invent them.

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MATTER Journal of New Materialist Research

Universitat de Barcelona
http://revistes.ub.edu/index.php/matter/about

Review of the Book: *Exposed. Environmental Politics and Pleasures in Posthuman Times* (Alaimo, Stacy, 2016)

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DOI: https://doi.org/10.1344/jnmr.v3i1.38968

Exposed is a collection of six chapters, along with a preface and a concluding section, most of which appeared in earlier versions in various journals in the course of almost ten years before the publication of the book. The chapters are grouped into three sections, entitled "Posthuman Pleasures," "Insurgent Exposure," and "Strange Agencies in Anthropocene Seas," and while the section titles provide a clear indication as to the themes of the chapters within, I would like to focus this review on four aspects of the text that seem to appear throughout it. As in much of New Materialist writing, these themes crisscross boundaries between the style and content of the writing, the internal logic of the argument and the external influences that shaped it, and, perhaps obviously, between "nature" and "culture." The four aspects are: (1) the key relations that shape Alaimo's book and manner of argumentation; (2) the ethical aspect of the text (both as an ethics of reading and ethics in general); (3) the multifaceted question of exposure (metaphorical, chemical, physical etc); and (4) the joys and pleasures present in the book and offered by it.

Relations

As Alaimo writes in the Acknowledgements section of the book, "nearly every chapter was sparked by an invitation to speak at an event or write for a collection" (p. 189). This, along with the obvious revisions, rereadings, discussions and editing over the ten years between the initial articles were written and the completion of this collection, makes the book – even before the reader actually gets to approach it – appear as

shaped by a wide number of relations: between Alaimo and other scholars, writers and artists, between Alaimo and the institutions she was invited to speak as and write for, and even between Alaimo and her earlier selves who were the authors of the first version of the chapters.

This initial observation only deepens along with the analysis of the book's six chapters, most of which are framed as reactions to events, pieces of art or readings, spurring further associations, inspirations and confrontations. For example, in chapter six, building on her work in *Bodily Natures: Science, Environment, and the Material Self*, Alaimo asks "to what extent trans- corporeality can extend through the seas" (p. 122). In her search for an answer, she moves through meaningful interactions with, among others, William Faulkner, Charles Darwin, *The Island of Dr Moreau*, Gilles Deleuze and Felix Guattari, "the poetry of Linda Hogan; the science writing of Rachel Carson, Neil Shubin, and others; the scholarship of Stefan Helmreich, Mark McMenamin, and Dianna McMenamin" (p. 113), artists Katrin Peters or Marina Zurkow, as well as fellow new materialist scholars like Karen Barad and Rosi Braidotti.

The sheer number and variety of sources may at times threaten to cloud Alaimo's own argument, which is often most clearly presented in the last few paragraphs of each chapter, but what it does most of all, is present the author as a careful, insightful and demanding reader, whose relations with the material are guided first and foremost by her posthumanist purpose – the need to find an adequate way to think, write and act in a world where humanist categories and thinking habits are still deeply rooted even in discourses which purportedly reject them (see, e.g., the discussion of "sustainability" in the Conclusion).

Ethics

The demanding nature of the engagements with other authors – as well as artists and activists – is driven first and foremost by an ethical motivation. This is clearly visible, for example, in Alaimo's criticism of Ian Bogost's *Alien Phenomenology* (Bogost, 2012), where the key point (aside from finding a humanist, masculinist residue in his work) is that such a simplified "flat" ontology throws the baby out with the bathwater

by "quash[ing] the animal studies arguments for animal minds, animal cultures, animal communications" (p. 179). In other words, while posthumanism needs to make possible the engagement with all beings – sentient and non-sentient, human and nonhuman, living and otherwise – it also needs a deep appreciation of the enormous differences there are between the beings that we characterise as belonging to these classes. Sometimes a generalised "posthumanism" may be worthless in the practical sense of the term. As Alaimo emphatically puts it, referring to the "alien" phenomenology of a ribbon cable:

> I cannot drink the Kool-Aid here and believe that a cable experiences anything at all; nor do I find it useful – personally, intellectually, ethically, politically, or in any other way except for perhaps as some sort of psychedelic koan – to imagine what it is like to "be" a cable (p. 181).

It seems that the most important strategy Alaimo uses to steer clear of such empty exercises in posthumanism is to ground her writing in experience(s). This is clearly visible, for example, in chapter three ("The Naked World"), where she analyses a number of environmental activist movements whose common strategy is to get naked. Obviously conscious and critical of the various connotations of the naked (female) body and the history of its abuses in visual arts and elsewhere, Alaimo nonetheless endeavours to treat such acts as potentially powerful political statements. As she concludes:

> While politically effective, (…) the naked protests do something more. (...) Disrobing, they momentarily cast off the boundaries of the human, which allows us to imagine corporeality not as a ground of static substance but as a place of possible connections, interconnections, actions, and ethical becomings. Exposing themselves, they dramatize how the material interchanges between human bodies, geographical places, and vast networks of power provoke ethical and political actions (p. 89).

Thus, in Alaimo's reading of these protests, they not only seek to use the body as an effective political tool, but in doing so, they also shift many of our theoretical and practical presuppositions concerning the relationship between the body and the world, (female) nakedness and nature, the human subject and the place in which it acts.

Through learning from those “eccentric” (p. 89) practices, Alaimo seeks to find new ethico-political theories that would take those shifts into account, resulting in a more thorough link between theory and experience.

Exposure

This strategy – starting from experience, and having theory follow it to avoid the pitfalls of a top-down approach – is also visible in how Alaimo approaches a particularly problematic type of exposure, namely the exposure to criticism. In what I read as a moment of both professional (as an academic) and personal (as a person who seeks to think and act in meaningful ways) exposure, Alaimo addresses a particularly stinging question raised by Claire Colebrook in her essay “Not Symbiosis, Not Now: Why Anthropogenic Climate Change Is Not Really Human” (Colebrook, 2012). Colebrook asks if

> all the current counter- Cartesian, post- Cartesian or anti- Cartesian figures of living systems (along with a living order that is one interconnected and complex mesh) were a way of avoiding the extent to which man is a theoretical animal, a myopically and malevolently self- enclosed machine whose world he will always view as present for his own edification?” (Colebrook, 2012, p. 198-199).

In other words, Colebrook suggests that the theories which seek to upend the Cartesian understanding of subjectivity and paint a more symbiotic understanding of the relationship between the human and other subjects (and objects) in the world, actually reinforce Cartesianism by refusing to see its lingering presence in their theories. This is particularly stinging to Alaimo, who counts herself among those who do see the world as a “complex mesh.” Exposing herself to this line of criticism, Alaimo answers that maybe it is through a direct engagement with the world – or more precisely, through the starting of our theorising from this direct engagement – that we can find alternatives to such theoretical myopia. The particular example she gives in the book is problematic, since her argument focuses on multiple chemical sensitivity (MCS), an illness unrecognised by science-based medicine. However, the stakes of her writing are quite clear: the strongest defence she has for her anti-Cartesian thinking is rooting it in experiences of concrete people and tracing “both an experiential and theoretical grappling with the precise ways in which self and world

are intermeshed" (p. 159). Theory, thus, should focus on seeking out and elucidating already-existing experiences rather than on normative wishful-thinking that Colebrook unmasks.

The titular motif of exposure does not come only in the theoretical variety (exposure to counterarguments) and the chemical variety discussed in the case of MCS; it permeates the book as a whole, again, in a practical rather than a theoretical way. Of course, Alaimo does provide some discussion of the concept itself – for example, in the introduction, she refers it to the problem of the untenability of the notion of the "impermeable Western human subject" (p. 5), or in the conclusion, where she discusses the different meanings and stakes of exposure depending on a given subject's race, class, ethnicity, political circumstances etc. But most importantly, she exposes exposure in its numerous dimensions, from the simple practice of nakedness to pondering how suffering from gall bladder or kidney stones can make us question the integrity of our own bodies.

Joy

It is perhaps in these fragments that the book is at its best – not when the relative merits and downsides of theories or concepts are discussed, but when the focus is set on the material practices of the artists, activists and protesters, or simply observations of the cultural environment. Alaimo has a keen eye not only for textual subtleties, but also – in this context, especially – for the everyday intricacies of life itself, sometimes in their most whimsical aspects. The book's highlights include the descriptions of the complicated power (and specular) relations between the activist-poet La Tigresa and the puzzled loggers in front of whom she is stripping in order to protest their actions, assessing the environmentalist and emancipatory value of the "Fuck for forest" movement (whose name succinctly describes their *modus operandi*) or "parodically hypermasculine modes of consumerism" (p. 95) which include, among others, the hanging of metal testicles from car trailer hitches.

Obviously, not all of the practices Alaimo analyses are those of exuberant joy, and although the book's subtitle contains the word "pleasure," there seems to be fewer and fewer pleasures as it goes on. But it seems that the idea behind this collection – a linkage of exposure, politics and pleasures – does shine through even the darker parts of the text. What *Exposed* seems to propose is an ethical incentive to seek pleasure out – not in a Freudian sense of "pleasure principle", and especially not in an egoist, masculinist way whose metonymy is Bogost's *Playboy* bunny story (p. 236) – to appreciate it theoretically and practically, and to include it in our array of political actions. And in this aspect the book largely succeeds.

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MATTER Journal of New Materialist Research

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Review of the Book: *Ways of Following: Art, Materiality, Collaboration* (Kontturi, Katve-Kaisa, 2018)

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DOI: https://doi.org/10.1344/jnmr.v3i1.38969

Ways of Following brings the compelling figure of following to the fore—for artists, curators, audiences, and readers. More than a figure, the book proposes following as a relational, force-ful, material process—a process that activates this text, in the same way that it has the work of its author herself, as a writer, artist, curator, collaborator and audience-member. Just as art has the "potential to make a difference, to challenge habitual ways of being, thinking, and feeling" (p. 9), so too does writing about and with art and artists. This is what Kontturi calls "writing with…processes and flows" (p. 11). There is an admirable bravery to this project's commitment to follow these processes and flows wherever they might take her and us. In this review I will attune to the materiality and collaborations of Kontturi's new materialist practices as an artist, writer, and art historian. I will follow the book's vital and provocative contributions to new materialist research in the arts, process philosophy, feminism and beyond, beginning with a summary of the book's structure and methodology.

After an opening that situates the author and the affective materialities of art and its followings, the second part of the book finds vital ways to encounter the work of artist Susana Nevado. Here 'encounter' and 'work,' along with other taken for granted terms, are infused with new life and vibrancy in Kontturi's writing, as the artists' practices and the author's engagements with them unfold. Moving personal stories, evocative descriptive passages, and process philosophical musings weave together to make the fabric of these chapters.

In the third part of the book, Kontturi returns to the sensuous proximity and the sensual relations that have been drawn out across the text. The focus on the mouth is

particularly, painfully, joyfully intense—for Kontturi, for audiences, and for me, as reader. The text which writes with Nevado's work is enlivened by material remembering:

> Staring at those primal teeth arouses visceral sensations: the body shivers, goosebumps rise. As the teeth connect with the viewer's body, affect the body, they might awaken 'forgotten' potentialities of the body…" (p.140)

After the grimacing mouth, the rest of the third section lets the preaching mouth and the screaming mouth call us to encounter other works and their makings. Here politics and ethics 'zigzag' energetically and sensuously across the pages of the book, through encounters with the collaborative Sappho Wants to Save You and the work of artist Helena Hietanen.

In the final chapter, Kontturi foregrounds the significance of the material turn in critical theory. She offers a 'follow-up,' with three propositions, circling around ontology, ethics, and politics. Art as movement, art as moving, art as volatile have woven through the book and return to the foreground here and help us remember, materially, the ethics and politics of following and their importance to new materialist research.

As a reader, I am struck by how a sense of movement structures the book, returning to the same artists—artists like Helena Hietanen and Susana Nevado—in different ways, different contexts, bringing to life (differently each time) the studio, the artist, the process, the collaboration, the making, and the work. As following winds its way—winds our way—through the book, it evokes a moving and dynamic relationship between the writer and the artist and the work.

As a methodology, as well as an ethics and politics, *Ways of Following* is a collaboration with theory and theorists, including feminists, new materialists, process philosophers and art critics. It is richly textured between philosophical and aesthetic moments of engagement. As more-than philosophy and more-than art history, the book breathes new immediacy, and immediations, into both. What particularly strikes a chord for me in Kontturi's methodology is how she refrains from illustrating theory, just as she sidesteps representing art. She deftly holds at bay, for instance, the sort of problematic philosophical abstraction that is often found in writing around and in the name of Deleuze and Guattari, two of her theoretical co-composers. The book instead

craftily inhabits their and others' theories with which she engages. While she finds the work of Deleuze and Guattari, along with Erin Manning, important guides to her project and while her engagement is deep and serious, nonetheless, these thinkers do not emerge as heavy-handed authorities. As Kontturi chooses to dance around and with each theorist and artist, she keeps them and their work in flux, ever available for her and the reader's re-thinking, experiencing anew. And so, as she aims, her book "overcomes the kind of analysis that detaches art from its process of production." (p. 11) What is especially affective, and important here, too, is how we are summoned to sense the liveliness of this process for Kontturi herself—a liveliness which animates her own process of research and writing into and for the unknown. This methodology—and its ethics, politics and insights—make *Ways of Following* an important and inspiring contribution to the Sense Lab's Immediations series.

The Immediations series from the Open Humanities Press has provided valuable contributions to new materialist research and this book is a welcome concluding volume. As their forward anticipates, it is through transdisciplinary co-compositions that "thought is lived…most intensely at the crossroads of practices and is enlivened in the weave of a relational fabric". And *Ways of Following* brilliantly fulfills this promise, weaving its own unique relational fabric through art, materiality and collaboration. Kontturi summarises the relational materiality of her own writing practice:

> Writing is a practice that necessarily co-emerges with multiple more-than-human companions, and so I want to begin by acknowledging the climates, computers desks, and even the fabric of the dresses I have worn during this book's composition…From weather patterns to felt textures, and everything in-between (including the cockroach that poignantly left its mark on my conceptual fashioning of the particle-sign), these co-emergences have been indispensable to this book's coming-to-being (p. 234).

This writing practice, woven as a fabric, woven with other humans and more-than-humans, follows Kontturi's following practice as an art historian and curator. And these figures, fabric and with-ness, call out to readers throughout the book, inviting us to follow, to experience, to collaborate in a new materialist writing and thinking and

doing practice. As an artist and theorist myself, I find these figures particularly compelling. I respond critically and affectively to the call of 'with-ness'—its call for an ethical and political response, a moving with, researching with, writing with, thinking with. While with-ness is not a new figure for new materialist researchers, I find its elaborations here enlivening and thought-provoking, as they are deeply grounded in thought and practice and the writing itself. With-ness animates following as a practice and is woven into the fabric of *Ways of Following*.

Like with-ness, fabric is more than a figure – it is structural and material. Fabric deftly intertwines the book, from attentiveness to the fabrications of art-making and art-writing, to the fabrics with which artists work, to the fabrics Kontturi herself wears in her own makings and writings, as I cited above. And there are also the fabrics that move and move with art, its audiences, and its spaces. Kontturi offers a compelling example from Sappho Wants to Save You, a work with which she was involved as both a maker and curator:

> Six full-body portraits of women hang in the air, filling the exhibition space completely; making it dense and intense. But the prints do not just hang there; they oscillate in the air, moved by passers-by and also by their technical construction: the fabric of the screens is light enough to be affected by the currents of air created by the audience and the air-conditioning, [and] the wired hanging system (p. 200).

In attuning us to how the materials, the spaces, the atmospheres, and the audiences are part of the fabric of an art assemblage—an assemblage that makes the intensity and density of a work— Kontturi also helps bring to life a new materialist understanding of art as always relational, always more-than and always in movement.

Movement, in all its agitations, suggests a third figure, besides fabric and withnesss, that resonates for artists and writers and that particularly spoke to me. That figure is stuck-ness. Kontturi is certainly not one to resile from stuck-ness—in her research or in her writing. Uneasy as it is, stuck-ness, for Kontturi and the artists she follows, is not a stopping or deadzone, but something full of potential, calling out to be to experienced. She learns much about stuck-ness, for instance, from one of the artists she follows most intensely and extensively, Susana Nevado:

> …in Nevado's vocabulary 'being stuck' means that the art process is still too strongly attached to the realm of the already known. In other words it is not a work of art yet; it is not working on its own (p. 108).

By following Nevado, Kontturi is able to recognize and relate to stuck-ness, as a moment of potential in the collaboration of an artist and her materials. Unexpected recognitions such as this takes time and a collaborative rather than judgemental relationship with an artist. Indeed, collaboration, as the subtitle tells us, is key to following as a practice. Kontturi's writing about art as a collaboration is fresh, and perceptive, co-composing along the way. Collaboration, in all its bodily relations, is both what Kontturi is following in her research and is itself a way of following. And, what we come to understand with this book is that collaboration is not just key to following but also key to a new materialist approach to art history—an approach which avoids the all too familiar individualizings and judgements in traditional art historical writing. Like other new materialist practices, following is deeply ethical in its concerns and methods and collaboration is integral to this. It is collaborative ethics that compels Kontturi's refusal of a judgemental (or patronizing) "godly eye". It is what also animates the sensuous, ever moving proximities of following and attentiveness to art's potentials. As Kontturi puts it:

> Instead of keeping a critical distance, following allows for sensuous proximity…The practice of following is dependent on the idea of art as a field of the future: there would be nothing to follow if there was no movement. (p. 140-141)

In this collaborative relationship, the artists are not the all-too-often mute, static, given material for the writer but are themselves complex, active makers who resist easy recognition or fixity. They are not to be taken at face (faciality) value. They call out to be followed. By avoiding a distancing, judgemental approach to the humans and more-than-humans with whom she collaborates, Kontturi models an important new materialist approach to art history, an approach that ethically and collaboratively foregrounds the materiality and process of art making and art writing.

Finally, I'd like to echo the book's concerns about why and how art matters and why and how the materialities of art matter and call for our encounter and engagement.

These are the questions, the problems, that activate Kontturi's important project. And while it is not a book about answers, but rather following propositions and processes, *Ways of Following* nevertheless affords us a re-freshed sense of how art might play a vital role to "change our thinking-feeling" (p.193). As Katve-Kaisa Kontturi's work manifests, "[Following] keeps offering new flows of process to follow, and therefore also new sensations to encounter and conceptions to create" (p.141).

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MATTER Journal of New Materialist Research

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Review of the Book: *Theory of the Object* (Nail, Thomas, 2021)

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DOI: https://doi.org/10.1344/jnmr.v3i1.38970

"What makes possible the existence and persistence of a mundane object like the ketchup bottle I hold in my hand?" (2021, p. 3) As in his previous works, Thomas Nail finds a manner of writing that manages to elaborate a very different style of thought in ways accessible to laypeople. "We live in an age of objects", (ibid., p. 1) he opens, and the innovation he seeks to immediately introduce, the central problem he wants to tackle, is to think a kinetic object. That is an object as "a metastable formation of matter in motion." (ibid., p. 4) A world then, that is all matter as motion and difference, and what appears stable is so due to relative difference of movement. A central problematic that emerges is how to explain that for much of Western history thought, the world or abstraction in general, whether as ideas in philosophy or numbers in mathematics, were anything but conceived as primary motion. To be successful, Nail's argument will explain how (the illusion of) stasis [the capacity to treat as if static] emerges out of constant motion. As such, Theory of the Object expands on the theory of motion established in his earlier magnum opus, Being and Motion (Nail, 2019). "We may find it useful sometimes to treat objects as if they were static, but when we do we tend to overlook what creates, sustains and changes them." (2021, p. 23)

A philosophy then, that can account for both change (as primary) and the appearance of stasis. Nail demonstrates in a few paragraphs how philosophies up to know, whatever their differences, have one thing in common: "... all four theories start with a division either between subject and object or between object and relation." (ibid., p. 10) The four theories are constructivism (any correspondence between an object and what a subject thinks of it is arbitrary), objectivism (or naive realism), but importantly

also relationalism (here in the example of Actor-Network Theory ANT) and object oriented ontologies OOO (here mostly thought through via Graham Harman). Much like the latter two, Nail's own project is enabled by the work of Gilles Deleuze, as is evident in the problematic itself, as well as the references such as Lucretius or Whitehead. The author however wants to create an alternative to the more dominant strands of relationalism, where he includes Deleuze's works themselves, as pure becoming happens outside of history, outside of materiality (ibid., p. 12), and OOO, where change happens in the hidden parts of objects that transcend the world. I would frame Nail's main innovation with regards to the subject/object or object/relation framing as residing in an approach where both of the pairs come to be formed out of one movement that comes to differentiate itself into these distinctions. Movement as material process in Nail's philosophy is indeed primary and all that comes to be formed in relative stasis is always already entangled. Meanwhile, the author states clearly that there are many objects that are outside of human worlds: “The universe creates all kinds of objects that have nothing to do with humans.” (ibid., p. 284)

The objects Nail is most concerned with are numbers. And for good reason, as they are so central to what is considered science and are commonly treated as ahistorical. “The aim of my history of science is to show that there are four main kinds of objects. The first one I call ‘ordinal’ because it develops through linear sequences. The second I call ‘cardinal’ because it creates and organises wholes or units. The third kind of object I call ‘intensive’ because of its highly differentiated internal structure. The fourth I term ‘potential’ because of its unspecified or yet-to-be-determined range of possibilities.” (ibid, p. 13 – 14) And then, there are the contemporary objects, co-existing with these past ones. This new kind is termed ‘loop object’, and its “main features are its hybridity, indeterminacy and relationality.” (ibid., p. 14) While these kinds of objects are increasingly abstract (and thus seemingly immaterial), they acknowledge “the priority of indeterminate movement” (ibid., p. 279), that is something as always outside of control and givenness. All the while a difference between indeterminate movements as nature and the ones modeled as mathematics remains, the latter remaining on some level always deterministic. Thus, there is always a difference between objects that come to be through matter in motion, and matter in motion as mingled with human technological activity. What remains to be explained

is to why when all objects come to be through motion, are many treated as if they were ideal, preexisting the world.

There is a material movement that generated the conditions for such retroactive projection to appear where at some point numbers begin to be treated as if they were primordially immaterial. All the while, as Nail strains to repeat, different kinds of objects persist – this is not a subsumptive teleological history. As a reader with an anthropological background, I find that the new practice of treating things as if , and the material infrastructure that upholds this ability, gets somewhat sidelined, which rather than being detrimental to the argument merely demonstrates how the book opens up pathways for new research. Here, importantly, even the abstract, the immaterial is still, unlike in dominant readings of Deleuze for example, partly material. Nail further clarifies that treating objects in certain ways, precludes other ways of engaging with them (ibid., p. 65). A reality then, that is local, horizontally constructed and splitting into different versions.

The project explicitly enters the most basic contemporary scientific discussions: “It begins from the historical discovery of quantum flux and then tries to explain the emergence of stable scientific knowledge.” (ibid., p. 11) For a reader steeped in science technology studies STS, including especially post-ANT research (such as the work of John Law or Casper Bruun Jensen), media archaeology and media philosophy (especially that of the German variant), and certain strands of anthropology that engage topics such as mathematics (e.g. Helen Verran, Ron Eglash), this cross-pollination is not exactly new. What Nail does that is new, is to include pre-history in his story and, following a similar pattern found in his Being and Motion, to explain how different eras of history were conditioned by different types of numbers that emerged from material movements, in order to demonstrate that numbers among others, are not ideal entities, but rather objects among others. It is in the empirical parts, where some limitations emerge, as none of the above-mentioned literature is referenced. I will return to the limits and generative possibilities for future research this lack points to.

Another major point is Nail's productive (re)definition of science. As he attempts to draw “connections across history, philosophy and science, looking for a bigger picture

than each discipline usually offers on its own", (ibid., p. 3) without building a hierarchy between science and philosophy, he comes to be concerned with objects that come to be made through science. He develops "a process theory of science and knowledge as the creation and distribution of objects-in-motion." (ibid., p. 283) In other words, "[he] define[s] 'science' quite broadly as the creation and ordering of objects as quantities." (ibid., p. 65) This is a formal definition, and any (human or non-human) activity can make the cut, such as bringing sticks from the periphery to the center thereby establishing this very distinction. Thus there were "three major prehistoric sciences: tool-making, signs and tallies." (ibid., p. 75) Meanwhile, science differs from art and politics: "For better or worse, science is the human practice of focusing on the quantitative dimension of things to make and arrange objects in new ways. The arts tend to do something similar by concentrating intensely on the qualities of things, and politics by focusing on the relations between things." (ibid., p. 65) With quantity and quality being intertwined as materiality, the lines between science and art become uncertain, focusing presumably on what aspect comes to be dominantly folded than what an object is. Or, I dare say, how it comes to be treated as if (an object was primarily quantity or quality). A human is a mobile body (extensive and intensive) and never simply separate: "There is no absolute division between a user and a tool, but only a relative difference depending on one's position in the operational sequence." (ibid., p. 75) To put it in other words, text and context constantly fold and are to be conceived materially.

Nail's is truly a process philosophy of science, lucidly demonstrating how distinctions appear through different movements and don't simply preexist the world. In this way, anything creates. He muses: "Why is it that when a human draws a fern it is art, but when matter grows into a fern, it is not? When humans keep track of a solar day with a calendar, we call this science, but when plants do it, we call it mechanical response. Why?" (ibid., p. 47) What humans do is part of the same decentralized process of creation and cross-pollination, without hierarchy. How is this possible? "In brief, matter flows indeterminately, then folds up and cycles into metastable objects, and is then distributed with others into fields." (ibid., p. 13) What is considered knowledge then, as well as technology and infrastructure, is the metastable result of the same process always on the verge of dissipating and folding into something new. That is,

“knowledge does not represent the world but is part of the world. It is the way the world weaves and orders itself.” (ibid., p. 49) Such definitions articulate what can be discerned in the entire conception of the book and the reason for why it is such a valuable entity and will certainly generate many effects far beyond specialist fields. The different simplifications and omissions Nail repeatedly refers to are without a doubt necessary for writing a book that performs a different type of thought for some of the most stubbornly held cultural conventions in science and the image of science.

It is however here, in what is purported to be a formal definition, that Nail's thought begins to short-circuit. Since his historical account of the emergence of new objects is based in one specific geo-locality, namely the line from speculation on Mediterranean-centric prehistory, through Ancient Mesopotamia, Greece, Euro-centric Middle Ages to Euro-Modernity, the content (the way Nail imagines how humans and objects come to be through the kinetic process) becomes the form. This is not a problem for the theory per se, as form and content emerge from the same movement, it is rather an issue because the lack of comparative materials (of other content/form emergence of human-adjacent realities) makes it impossible to become aware of the very specificity of the argument than Nail, however self-limiting, seems to be aware of. It leads to an overstatement of the centrifugal movement in relation to the centripetal, whether in terms of the center-periphery emergence thoroughly discussed in the first part of the book, or the movement between different centers and peripheries (what could commonly be called different techno-cultures), as well as their entanglements (what is center somewhere is periphery elsewhere). These are of course anthropological concerns, but Nail necessarily engages anthropological problems and offers a grand narrative to substitute how humans came about, where he shifts the focus toward the emergence of science and objects, through material motion, which still includes humans and the objects and other things that come to be through this formation. Importantly, the points I am about to expand and Nail's project do not exclude each other, far from it, they are mutually generative for further research, and Nail's book does propose a conceptual infrastructure to connect all these various strands and expand our understanding of what is possible in the world as far as science and the emergence of objects goes.

As Édouard Glissant, and Deleuze (in Islands) for that matter, make clear, there are radically different (incompossible) ways of thought in this world. And they come to be made through the environments that are folded into thought. As the German media archaeologist Siegfried Zielinski (2006, pp. 25 – 26) points out, for Glissant, Caribbean thought does not turn around a center, as the West and Near East with it's clear distinctions between land and sea, nature and culture, light and dark, destructive and creative, invisible and visible (2021, p. 93). This distinction is already contained in the word, Mediterranean: in the middle of the lands. This lineage of thought points toward the one from which the other is distinct, and between which, as in Nail's favored center-periphery distinction, movement occurs. Whereas the Caribbean features only one "... standardizing [,] factor […] an invisible trace running along the sea floor – the chains of the slave trade." (2006, p. 26) An entirely different constellation from which thought (qualitative and quantitative) emerges. The imagery Nail draws on, further comes from lands where the figure is easily separated from the ground. Deserts with space between cities, oases, humans. For me, as a researcher that engages more tropical areas, it becomes very evident that in Southeast Asia or say, the Amerikas, the emergence of center-periphery distinctions, quality and quantity, given we follow a materialist account where the environment folds into fields, must have been very different. As appears evident with the formation of a mathematics by the Maya on other grounds than what we are used to, amalgam of different histories that 'our' mathematics are (Goodman 2016).

Further, as already Mauss & Beuchat (1906) pointed out, there are societies that change their organization and moral conventions with the seasons, as they move around following changing conditions, thus making a simple center-periphery distinction impossible, implicitly demonstrating that it only holds for a very specific type of sedentary society under specific bio-environmental conditions. Nail, with his exclusive focus on agriculture, also misses that many indigenous people's were (or perhaps continue to be) horticulturalists (turning the entire American continent into a sort of a garden) or pisciculturalists, among others. All of these arrangements make entirely different forms of abstracting possible, if we take, as Nail does, that abstraction emerges as part of condition-specific problem solving inherent in material processes.

Further, when it comes to signs and later the abstraction of letters (discussed on Nail 2021, pp. 79 – 86), the Yellow river basin, the so-called cradle of Chinese tradition, while probably not being as different from Middle Eastern conditions as jungles (where it is generally difficult to visually discern where one thing ends and another begins and emerging empires face entirely different organizational challenges that would lead to other kinds of abstractions), still came to form a unique different way of doing science, numbers and thinking (Hui 2016). One that until rather recently, much like the tradition of the Indian subcontinent reaching into other pasts unconsidered here, such as Mohenjo-daro, was far more productive when it comes to scientific innovation than the European one (with it's lineage to Sumer and Egypt, as retro-fitted in modernity). While it is not a problem per se that Nail doesn't engage any of this problematic, it is one that is not external to his project, as his prehistoric accounts draw on an imaginary quite evidently drawn from the Mediterranean (and it is well known that many areas had a very different kind of vegetation, biosphere than we know today) when thinking through how a process came to be formed in what were apparently densely forested areas of today's Europe. This is what I mean by a formal process becoming entangled with its content, and unfortunately quite explicitly teleological in the account of how ritual, labor division and power emerged (2021, pp. 92ff.).

When it comes to mathematics specifically, the development of material infrastructure that makes new types of mathematics possible, as certain things come to be done by (cultural) techniques, creating new conditions for the human mind-bodies that enter these fields and changing what can be thought and done, has been treated extensively by media theoreticians (e.g. Krämer & Bredekamp 2013). And anthropologists, such as Helen Verran (2001) and Ron Eglash (1999) demonstrate entirely different and very material ways of counting, of using the body for counting, of cities built as fractals (unnoticed by the colonial European perception which only projects its own conventions on the world) in different parts of Africa. Anybody who has ever traveled or watches world cinemas will have noticed there are many ways to count (to pass from material quantity to ordinal numbers), and is possibly even aware of the Gaulic manner of counting with 20, instead of our common ten, still preserved in the French language. To be clear, none of this contradicts in even the slightest way

the overall arch of Nail's project. Such knowledge merely points to an important pitfall that necessarily occurs, due to the limitations each of us has in our own positionality, namely that we take, analogously to the tendency to mistake ordinal for cardinal numbers, or quantity for quality (two of the main examples Nail uses), content for form. It is precisely why anthropological and media archaeological research will remain important as it (re)constructs comparative empirical examples that make it possible to conceptualize ever further aspects of reality that are not simply given or evident. So we return to the question of practice indicated but never treated by this philosopher: “There is a growing divide between ‘knowing how’ and ‘knowing that’; skill and knowledge are going their separate ways” (Krämer & Bredekamp, p. 26) The feedback loop between practices and material reshapings of the world have been thoroughly thought through by various media philosophers, and it is somewhat unfortunate that none of this appears in Nail's work.

However, he does explicitly acknowledge such limits: “the present work is limited to a particular geo-historical lineage from prehistory, to the Near East, and into Euro-Western modern scientific practice. In no way does this suggest that the West has the only or the best sciences.” (Nail 2021, p. 285) But when working through the material in detail, he does not heed his own parameters and repeatedly makes 'just-so' generalizations that inadvertedly betray his own standards.

Lastly, I can't shake the feeling that his method is deductive when it comes to the historical periodization. According to Nail, the “most abstract move in ancient logic” (ibid., p. 124), is one that presupposes some initially true statements and based on these arrives at logical conclusions that need not be tested against the material world. While Nail does 'test' statements, it still is as if the common way to delineate epochs was taken as a given and only then were developments that vaguely fit the periodization looked for. This is the generative power of the as if, but one cannot but wonder to how different results different periods and different sources would lead to. I suggested some lines of research above. Nevertheless, as repeatedly mentioned here, the theory can account for both its own emergence and varieties and possibilities outside of what is formed here, this never becomes a limit in general. After all, Nail clearly states how all of the different types of objects persist and as such make new

kinds of objects possible. “The objects we hold in our hands today are mixtures or hybrids of these four historical types.” (ibid., p. 67) All of which relates to the question of cosmotechnics, as opened by Hui (2016), that is whether the technologies, in other words productions of objects, today could be otherwise. In thinking the possibilities of technodiversity, the question of what it means for the quantum 'loop objects' Nail writes about immediately appears. It is precisely because all kinds of objects persist next to each other, that my examples have an import on all of the objects in Nail's book.

I hope to have shown, through the extensive discussion and examples of other imaginaries that even with philosophies conceived based primarily on movement (regardless of how innovative they actually may be) begin to split differently when encountering slowed down and reshaped fragments of the world. In other words, a theory becomes good, when it can be adapted to new information, when it can develop through new encounters. And one thing is clear, after reading Thomas Nail's Theory of the Object, it is one such book that will lead to many productive encounters and maintain its relevance, precisely because the conceptual infrastructure is kinetic. Perhaps especially when it comes to readers coming from backgrounds other than continental philosophy and theory-heavy anthropology and media studies, such as the analytic philosophy Nail at times refers to, this book can act as a bridge that will create understanding between a wide variety of scientific practice, as all of us can connect to the material processes Nail describes. Something that, admittedly, most of the research I engage and compare his writing to, will not. Precision, much like the use of common words, comes at an inverse price. Nail here, as in his other works, manages to find that fine line where common English does not yet fall into conjecture and biased unbased assumptions.

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