Digital twins as Technology of Transformation: A Transcendental Empiricist Perspective

Master thesis

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Summary

The thesis promises to be a solution to the problem that the way digital twins are currently being used, that is as technologies of control, creates experiences of oppression. The solution that the thesis proposes to this problem is to substitute the understanding of digital twins that leads to them being used as technology of control with a different understanding. The thesis argues that a different conceptual framework for digital twins could facilitate a different instrumentalisation of digital twins. The alternative use case that the thesis proposes is to use digital twins as instruments of transformation. This use case gains relevance due to the fact that contemporary views on tackling societal problems belief that these problems require a transformation of the systems that led up to these problems and because of that also a transformation in the way that is thought about these problems (Campbell et al., 2019; Schrickel, 2020). Therefore, the thesis addresses the question: *What could be a conceptual framework for digital twins that would enable them to be used as a technology of transformation and what adjustments are needed in the practices of digital twins to achieve such an instrumentalisation?* This question is answers by use so Gilles Deleuze's transcendental empiricism.

A conceptual framework for digital twins is developed by use of an empirical account of digital twins and the metaphysics of Gilles Deleuze. Digital twins that lead to experiences of control can be understood as a method for regulating the course of becoming of a phenomenon. Digital twins affirm the becoming of a phenomenon along a sufficient reason by use of their data-link and try to regulate the becoming by regulating the intensive differences with which a phenomenon comes into contact by use of the information-link. The mechanism that is used to legitimise digital twins, that is accuracy: predictive and explanatory power, leads to situations of oppression and control because it leads to the further actualisation of hegemonic sufficient reasons. The replacing of the legitimation mechanism with a mechanism that is based on intensification opens up the possibility to use digital twins as a technology of transformation.

Lastly, the thesis proposes the modification of introducing a post-deliberation inquiry process in practices of digital twinning for transformation. Simulations should be used as a way to experiment with the through intensification collected differential elements and form the starting point for making these confused perceptions more clear by attempts at conceptualising these differences. With the ultimate goal to develop a new sufficient reason that transforms experience.

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Introduction

Pushed forward as the bridge between the EU Green Deal and the EU Digital Transition Strategy (European Commission, 2020, 2021, 2024), digitally representing physical entities, processes and systems has gained popularity in recent years. This phenomenon that is referred to as digital twinning (Trantas et al., 2023; Rathore et al., 2021), or if treated as an object; a digital twin, promises to increase the ability to control and optimise operations (Trantas et al., 2023; Semeraro et al., 2021; Meierhofer & West, 2019; Oldenburg, 2022; Barth et al., 2023; Bauer et al., 2021; Korenhof et al., 2021; Alam & El Saddik, 2017). These promises are well received in a manifold of sectors; from healthcare to mining and from city maintenance to banking (Fortune business insights, 2022). An example of a digital twin in practice could be a digital twin of a building, where the digital twin makes sure that the building is in a pleasant condition at all times while keeping maintenance costs low. The digital twin does this by constantly monitoring the state of the building and actively proposing actions for keeping the building in the desired state. The digital twin is able to do this because of a bidirectional connection between a digital representation of the building and the physical building itself that exchanges data from the physical building to the digital representation and information from the digital representation to actuators in the physical building.

As mentioned, digital twins are used as instruments to control operations. As a result of this use case are digital twins conceptualised as instruments of power and control in literature in the domains of philosophy of technology and science and technology studies (STS). Digital twins are for instance conceptualised as a technology of control (Helbing & Sánchez-Vaquerizo, 2023), a technology of governance (Kloppenburg et al., 2022), or even as a “technology of singularization” (Turnhout & Lynch, 2024, p. 3) meaning that digital twins force a technological logic that eradicates human and non-human (animals, plants, ecosystems) logics. The responses in literature to these conceptualisations are to politicise digital twins and to raise ethical concerns about potential repression of ideas and groups of people. There are for instance accounts on non-epistemic values in digital twins (Bruynseels et al., 2018; Westerlaken, 2024) and on governmentality in digital twins (Turnhout & Lynch, 2024). The insights of this body of literature generally lead to a discussion about who should have the right to decide what happens with e.g. a forest and who should not, or lead to the development of methods to reach consensus between groups by attempts to intentionally incorporate a selection of public values in digital twins (Kloppenburg et al., 2022).

What remains underexposed in the current discussion on digital twins is that the way digital twins are understood (conceptualised) also affects the way digital twins are used (instrumentalised) and

thus the experiences they create. Digital twins are understood as means to control and optimise operations and are therefore used in that way and thus create situations of oppression. Further conceptually developing the discussion on control by the construction of political arguments or negotiation methods that promote consensus do not resolve the experiences of oppression that digital twins create. Furthermore, a rejection of digital twins all together as Turnhout & Lynch (2024) propose, also does not resolve experiences of repression since it only leads to an experience of repression by the those who wish to deploy digital twins. The only way to go beyond experiences of repression created by digital twins is by instrumentalising digital twins differently. For this it is necessary to understand digital twins differently; to have a different conceptual framework for digital twins.

In addition to the use of digital twins as technologies of control, are digital twins presented as means to address societal problems such as environmental challenges like “climate change, biodiversity loss, and resource depletion” (Kloppenburg et al., 2022). Take for instance the digital twin project Destination Earth of the European Commission that is intended as an aid to support sustainable developments (European Commission, 2021). Contemporary views on tackling societal problems belief that these problems require a transformation of the systems that led up to these problems (Campbell et al., 2019). As Campbell et al. (2019) discuss, transformation goes beyond finding ways to meet consensus between stakeholders in a just, democratic way. Transformation requires a new logic, a new structure that gets to be institutionalised. Consider for example the United Nations (UN) Sustainable Development Goals that aim at transforming socio-economic and socio-technical systems to systems that are considered sustainable (UN, 2025). Transforming systems also requires a transformation of the way of thinking that led to these systems, in other words societal problems require a transformation in how is thought about these problems (Schrickel, 2020).

Although there is a need for digital twins as instruments of transformation, this use case is underexplored in the literature on digital twins. Furthermore, current digital twin practices also seem underdeveloped to realise transformation. A specific conceptual framework for digital twins for this use case could foster the further development of practices of digital twinning for transformation. Moreover, it provides the opportunity to go beyond the instrumentalisation of digital twins as technologies of control. Therefore, this thesis addresses the question: *What could be a conceptual framework for digital twins that would enable them to be used as a technology of transformation and what adjustments are needed in the practices of digital twins to achieve such an instrumentalisation?*

The approach: Transcendental empiricism

The difficulty in answering the research question is that there is no empirical case from which a conceptual framework could be derived, since there is no case of digital twins as instruments of transformation. A specific conceptual framework could help the development of practices of digital twinning for transformation and meet the need that is expressed. However, as mentioned, there is no empirical case from where such a framework could be derived. Thus, we end up in a paradox that limits us in developing a new conceptual framework for digital twins, even though there is a need for it. Gilles Deleuze's transcendental empiricism is a method to break open this paradox (Smith, 2015) and will therefore be used to formulate an answer to the research question of this thesis.

The aim of transcendental empiricism is to create new forms of being (new forms of life) by letting yourself be affected by the world. This means to embrace the new possibilities of life that change (events) bring (Prášek, 2024). The method takes up both the critiques of empiricist philosophies on transcendental philosophies as well as the critiques of transcendental philosophies on empiricist philosophies (Rölli, 2016). The transcendental method takes transcendental ideas as its source for philosophical inquiry while empiricism takes experience as its starting point. The empiricist's critique on transcendental philosophies is that it is disconnected from experience and therefore not applicable to real life. As a result of this critique commits transcendental empiricism strongly to experience (Rölli, 2016). The transcendental critique on empirical philosophies resolves around its assumptions about consciousness. This critique could be summarised to the premise that empirical experience is conditioned by the transcendental ideas that the observer holds (Smith, 2015). Therefore, abstraction from empirical experience leads to a repetitive loop that disallows new ideas to emerge; ideas are re-cognised rather than created (Deleuze, 1994, p. 144). Mere abstraction from empirical experience ("lifting off"), is thus not enough to go beyond the conditions that determined the empirical experience.

Transcendental empiricism attempts to escape the transcendental ideas that determine the empirical experience and substitute them with new ideas that determine the empirical experience differently. This method could be used for the problem of developing a conceptual framework for digital twins to fosters transformation. By substituting the conceptual framework that led to the empirical experience that is conceptualised as a situation of oppression and control (Turnhout & Lynch, 2024), the possibility for digital twins to become something different than an instrument of control is opened up. By doing this I am not denying nor neglecting situations in where digital twins act as technologies of control, rather I intend to open up a broader range of possibilities of what digital twins might be and how their practices might develop further.

To break open the loop of re-cognition and open up new possibilities of being, Deleuze (1994) conceptualises the relation between the empirical and the transcendental as one that is based on difference rather than resemblance. For this, Deleuze develops a conception of difference that is positive, meaning that difference is not the relation between things that differ but that it is something in itself, that it stands on its own. Deleuze's concept of difference concerns "difference-in-itself" (Deleuze, 1994). When something changes – differentiates – the new identity that emerges is not conditioned by the old identity that was surpassed, but by the differences that condition the new identity. Rather than understanding difference as being in-between two identities, Deleuze understands identity to be in-between two moments of difference, in-between two events. Consequently, Deleuze does not speak of being but of becoming.

To put this differently, Deleuze redirects the focus from phenomena – things – to the events that condition the forms phenomena take on. Because phenomena result out of events, events have the capacity to bring forth forms of being (Prášek, 2024). Deleuze beliefs that the forms a phenomenon takes due to events is merely a selection out of the multitude of possibilities that the event is rich. The event contains a multitude of possible forms that a phenomenon could take on. However, the potentiality of an event is closed off when a phenomenon gains its actual form (Deleuze, 1994). Transcendental empiricism intends to open up the potentiality of an event and actualise a phenomenon differently.

Because ideas determine experience and events determine the actualisation of phenomena, Deleuze equates ideas and events; they are the same thing. Transcendental empiricism could therefore be understood as the reconceptualising of events, moment of change, that are experienced. This requires attention to the conditions (events) that make phenomena particular rather than general – attention to what makes phenomena different. Therefore, to understand what something is we should ask questions like: "who? how? how much? where and when? in what case?" (Deleuze, 1967, p. 92). The difficulty, however, lies in deciding what an event is; to decide what conditions our experience and what is merely an effect of those conditions. Put differently, to distinguish between cause and effect. Though, this difficulty is partly determined by how well the philosopher carries out the method of transcendental empiricism[1]. For, the better the concepts the philosopher creates, the more likely they are to affect the world and become an event. Therefore, the point of transcendental empiricism is that concepts have the potentiality to become events – to affect the world – and

[1] Deleuze points to Spinoza as the last philosopher that produced a 'pure event' a truly new thought (Deleuze, 1988).

condition experience (life) differently. The approach therefore is concerned with the creation of concepts (Deleuze & Guattari, 1994).

Sub-questions

Based on transcendental empiricism is the main research question divided into sub-questions, each of which will occupy a chapter of this thesis.

Chapter 1 is concerned with the problem of substituting the conceptual framework that forms the basis of digital twins' instrumentalisation as technologies of control. The chapter addresses the question*: What could be a conceptual framework for digital twins that would enable them to be used as a technology of transformation?* To answer this question, the chapter makes use of Deleuze's transcendental empiricism and goes through three steps. First, are existing conceptions of digital twins that lead to the instrumentalisation as technology of control dissected. The conclusion of this analysis is that current conceptions create the need for a conceptual framework for digital twins that is grounded in a unified empirical account of digital twins and that is not "traced" to the idea of scientific representation as that leads to instrumentations as a technology of control. Second, is a unified empirical account of digital twins developed by use of a case study. This account explains the emergence of digital twins by the difference that digital twins are concerned with real-world phenomena instead of experimentally produced phenomena. Third, based on the newly developed empirical account of digital twins is a conceptual framework developed for digital twins that is grounded in Gilles Deleuze's metaphysics. This metaphysics forms a good basis for digital twins to be instrumentalised as technology of transformation because it emphasises the creative potentiality of reality and centralises change. By use of the newly constructed conceptual framework is an understanding developed of the current instrumentalisation of digital twins a technology of control.

Chapter 1 concludes that a different mechanism of legitimation could open up the possibility to use digital twins differently, potentially as a technology of transformation. Therefore, by use of the in chapter 1 presented conceptual framework investigates chapter 2 a mechanism of legitimation that supports the instrumentalisation of digital twins as technologies of transformation. Consequently, the chapter addresses the question: *What could be a legitimation mechanism for digital twins as technology of transformation?* The chapter goes through three steps to address this question. First, a legitimation mechanism for digital twins as technology of transformation is developed by use of the Bergsonian notions of true and false problems which Deleuze adopts in his work. Second, the developed mechanism is further nuanced with the help of John Dewey's theory of intelligent conduct. Dewey's theory is used to gain an understanding of the possibility of action while being in

an event; in a moment of change. Lastly, explores the chapter how the developed legitimation mechanism could become part of practices of digital twinning.

Chapter 3 explores how practices of digital twinning should be transformed to facilitate transformation with which it provides an answer to the sub-question: *What modifications in the practice of digital twinning are required for digital twins to be technologies of transformation?* The chapter explains the relation of Deleuze's ethics of the event to transformation and explores how Deleuze's ethics of the event can become part of digital twinning by means of the activity of gleaning. By building on the insights of chapter 2 are modifications to the practice of digital twinning proposed which mainly rely on the practices of data gathering, simulating and intervening. These modifications are explored in a case study that would benefit from the use of digital twins as a technology of transformation.

Chapter 1: **A conceptual framework for digital twins to foster transformation**

Introduction

In the technical academic discourse on digital twins it is assumed that digital twins provide us with representations of real-world phenomena that can be used to predict the behaviour of phenomena (Van Der Horn & Mahadevan, 2021). As a result of this understanding, digital twins are considered to be able to shape the existence of a phenomena to an ideal that could help us reach our pragmatic aims (Van Der Horn & Mahadevan, 2021). In literature in the philosophy of technology and philosophy of science is the first part, what digital twins are, conceptualised as an *in silico* representation (Bruynseels et al., 2018), a dynamic representation (Wagg et al., 2024; Wright & Davidson, 2020), or a steering representation (Korenhof et al., 2021). In another body of literature in the philosophy of technology and science and technology studies (STS) is the instrumentalisation of digital twins (the second part) conceptualised as a technology of control (Helbing & Sánchez-Vaquerizo, 2023; Kloppenburg et al., 2022; Turnhout & Lynch, 2024). The understanding of the first part; what digital twins are, has an effect on how digital twins are used; what digital twins do: digital twins create experiences of oppression and control for the actors involved with the phenomenon that the digital twin is concerned with (Turnhout & Lynch, 2024).

This chapter is concerned with replacing the conceptual framework that explains what digital twins are with a framework that allows to go beyond an instrumentalisation as a technology of control to an instrumentalisation as a technology of transformation. Consequently, the chapter aims at answering the question: *What could be a conceptual framework for digital twins that would enable them to be used as a technology of transformation?* This question is answered the following: Deleuze's transcendental empiricism is used to dissect existing conceptions of digital twins that lead to their instrumentalisation as technology of control and to develop an empirical account of digital twins that could form the basis for a conceptual framework that fosters an instrumentation as technology of transformation. The understanding of digital twins that is derived from the constructed empirical account is based on the metaphysics of Deleuze. This metaphysics forms a good basis for digital twins to be instrumentalised as technology of transformation because it emphasises the creative potentiality of reality and centralises change. Based on the new conceptual framework for digital twins is an understanding developed of the current instrumentalisation of digital twins.

Existing conceptions of digital twins

This section dissects the conceptions of digital twins that forms the basis for its instrumentalisation as a technology of control. First, based on technical academic discourse on digital twins I will discuss the practice of using digital twins as a means to optimise and control operations. Then I will assess the conceptions of digital twins that have been derived from this use case. Eventually I will conclude that existing conceptions of digital twins are unsatisfactory as they are derived from the transcendental idea of scientific representation and are empirically grounded only in a specific component of digital twins.

It needs to be mentioned that the order of emergence of a use case and a conception does not matter for transcendental empiricism. Even though the chronological order is that first a practice of digital twinning emerged and then a conception of digital twins and of their instrumentation, these conceptions still determine the experience of digital twins and the outcomes they cause. The conceptions of the event of digital twinning affirm the event in a particular way. Ultimately, these conceptions make the unconscious transcendental ideas that determine the experience of digital twin explicit, which allows them to be substituted.

Digital twins as a means to control and optimise operations

Looking at technical academic discourse, digital twins are generally understood as means to control and optimise operations (Trantas et al., 2023; Semeraro et al., 2021; Meierhofer & West, 2019; Oldenburg, 2022; Barth et al., 2023; Bauer et al., 2021; Korenhof et al., 2021; Alam & El Saddik, 2017).

> "The digital twin replicates the physical system to predict failures and opportunities for changing, to prescribe real time actions for optimizing and/or mitigating unexpected events observing and evaluating the operating profile system." (Semeraro et al., 2021, p. 15)

Digital twins are supposed to increase the ability of an operation to reach a goal (control) and improve the efficiency with which that goal is reached (optimise) (Tao & Zhang, 2017). A goal could for instance be a production target. In order to be able to reach a goal, a system often needs to live up to an ideal (a machine for example has to work perfectly to reach a production target). Digital twins help to bridge the gap between the actual performance of a system and the ideal performance of a system (Kowalkowski & Ulaga, 2017). Digital twins are supposed to prevent systems from "breaking down" and not meeting the ideal version that is required to reach the goal of an operation (Grieves & Vicker, 2017, p. 86).

To complete this task, digital twins are assumed to be composed out of a digital representation of the physical phenomena of interest and a data-information link that connects the digital representation to the physical phenomena (see figure 1) (Grieves & Vickers, 2017; Grieves, 2023; Liu et al., 2023; Ortt & Tiihonen, 2022; Rasheed et al., 2020; Sharma et al., 2022; Van Der Horn & Mahadevan, 2021). As the term implies, through the data-information link is data and information exchanged between the digital model and the real-world physical counterpart. The digital twinning process is considered to work as follows: first, data is collected using sensors that monitor the physical phenomenon. This data is processed, analysed and turned into information by the digital model whereafter it is used to inform actions related to the physical phenomenon. This process can be continuous and is often automated by use of various emerging technologies such as Artificial Intelligence (AI), Internet-of-Things (IoT), advanced sensory technology and high-speed networking technology (5G, 6G) (Korovin, 2022), or is intended to be automated in the future (Ortt & Tiihonen, 2022).

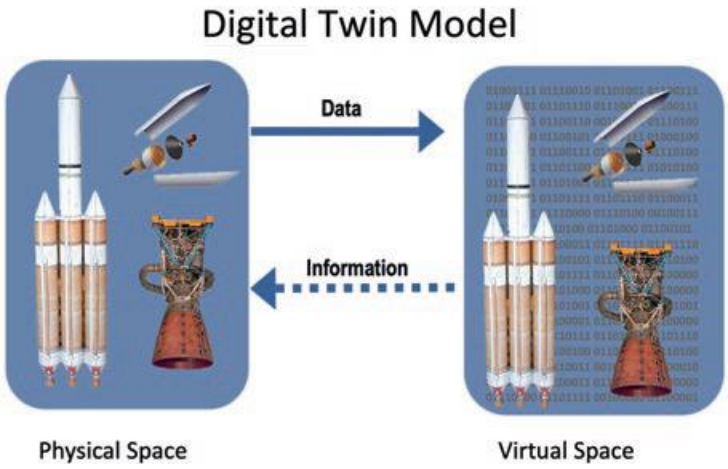

Figure 1: Schematic overview of a digital twin (Grieves, 2023).

The method that digital twins deploy to control and optimise operations is not inherently technological, rather the actions taken to execute the method are increasingly infused and substituted with technologies. The technologies of digital twins are used as a way to optimise operations by increasing the control over the operations. An example of a non-technological deployment of the method that digital twins intend to optimise by increasing control is a dune notch, or Kerf in Dutch. A Kerf is a passage from the beach to the dune area that has the purpose to blow sand into the dune area (see figure 2). This makes the dunes higher and gives the dune area more mass, resulting in better protection against the sea. In addition, a Kerf also contributes to the ecosystem of the dune area because the sand contains a lot of lime from shellfish, which is good for the plants that grow in dune areas (Arens et al., 2013).

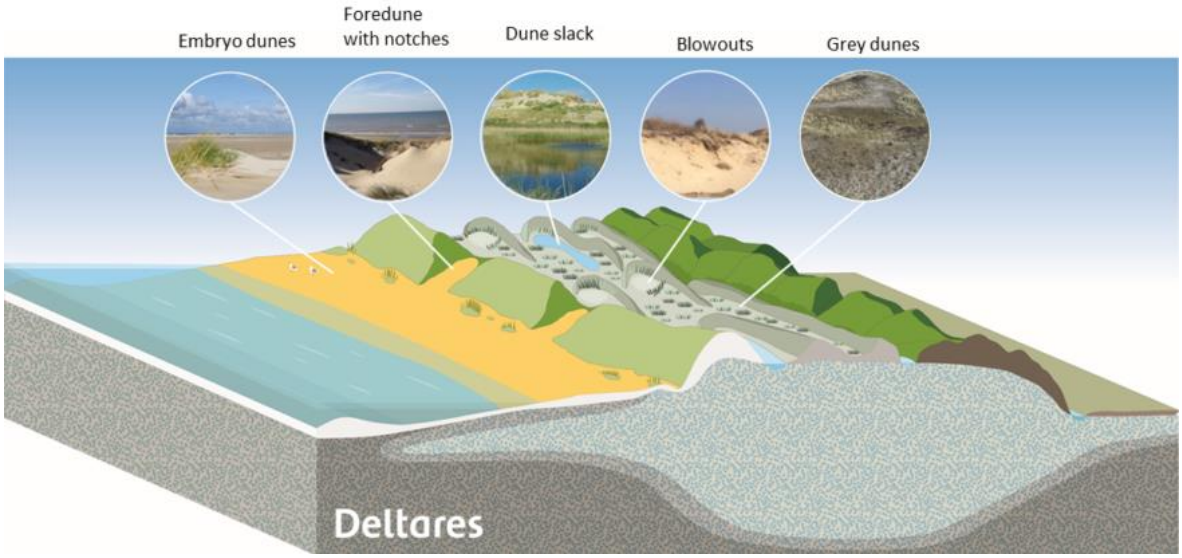

Figure 2: Diagram of a dune area with a Kerf (van der Valk et al., 2021).

A Kerf is an intervention to shape the phenomena of interest – the dune area – to an idealised form. In this example are dune areas understood as means to reach the goal of realising a pleasant living environment. Dune areas contribute to this goal in two ways: 1) by offering protection against the sea; and 2) by being a nature reserve. These two values of dune areas are threatened by coastal erosion (van der Valk et al., 2021). The Kerf must neutralise this threat and realise the two idealisations of dune areas. This intervention is informed by an understanding of dune dynamics and the dune area ecosystem.

To translate this to the digital twin terminology used above: there is a real-world phenomenon – the dune area – that is being represented by scientific representations – understandings of dune dynamics and dune area ecosystem – that are adjusted to the specific phenomena of interest (data-link). Based on the insights from these scientific representations is decided for the intervention of the Kerf that is deemed capable to realise the idealisations. Provided that the knowledge that informed the intervention – the Kerf – is reliable, the dune area is experienced as a protector against the sea and nature reserve. In this particular case could digital twin technology contribute to maintaining the Kerf to make sure that it functions optimally by performing checkups and making adjustments. The implementation of technology is supposed to provide more control over phenomena and more effective realisation of the goal that is pursued. Moreover, the technology also provides the possibility to perform simulations which makes it easier and less invasive to perform experiments.

Existing conceptions of digital twins

Attempts at conceptualising digital twins in the domains of philosophy of technology and philosophy of science demarcate digital twins by two things: 1) they contrast digital twins with conventional scientific representations, and 2) they fuel these contrasts by focusing on a specific aspect of digital twins. These two acts lead to conceptions of digital twins as a specific type of scientific representation, for instance an *in silico* representation (Bruynseels et al., 2018), a dynamic representation (Wagg et al., 2024; Wright & Davidson, 2020), or a steering representation (Korenhof et al., 2021). Combined form these concepts a comprehensive picture of the conception of digital twins that forms the basis for its instrumentation as a technology of control: the representations digital twins provide are digital (*in silico*), highly accurate (dynamic), and are used to shape the real-world phenomenon of interest to an ideal (steering).

This understanding leads to an instrumentalisation that results in experiences of oppression and control. Digital (*in silico*) models offers the possibility to perform simulations about possible behaviour of a phenomenon. The simulations provide insights into how a phenomenon responds to changes in conditions (Sharma et al., 2022; Korenhof et al., 2021). The data-link running from the physical phenomenon to the digital model enables the digital twin to be dynamic meaning that it adjusts the digital model to the latest deviations in the physical phenomenon. As a result of the data-link, the digital models of digital twins are considered to be 'up-to-date' and therefore highly accurate representations of the physical phenomenon of interest (Sharma et al., 2022; Grieves & Vickers, 2017; Grieves, 2023; Van Der Horn & Mahadevan, 2021; Rasheed et al., 2020; Korenhof et al., 2021). The information-link running from the digital model to the physical phenomenon is considered a means to steer the physical phenomenon to a desired – idealised – state. The acts of intervention that are used to realise the desired state are determined by insights obtained from the simulations provided by the digital model (Grieves, 2023; Rasheed et al., 2020; Korenhof et al., 2021).

The issue with the existing conceptions is that they conceptualise digital twins by opposing them with something else, with the result that one does not end up with a conception of digital twins but with a non-concept of the idea it is being contrasted with[2]. The conceptions understand digital twins

[2] Bergson's critique on the method of negation has a central point in his philosophy (Deleuze, 1988, p. 44). Negation is a method for defining concepts by use of what it is not (its opposite) (Horn & Wansing, 2022). Bergson's critique is that negation is too imprecise for it to tell us anything (Deleuze, 1988, p. 44). He states that negation starts with a concept (thesis) that is too big and because it is too big it encapsulates part of the opposing concept (anti-thesis). By, for example, a dialectical interaction between the thesis and the anti-thesis the boundaries of the concept and its negative (opposite) are defined until they are clear enough for the

as non-conventional scientific representations, or put differently, digital twins are a special type of scientific representation. The starting point of each of the above discusses conceptualisations is thus the transcendental idea of scientific representation. The conceptions can therefore be accused of being based on a form of idealism. Then, starting from the idea of scientific representation are empirical observations cherry picked to demonstrate that digital twins are a special type of scientific representation. This is how is ended up with a conception specific to the data-link of digital twins (dynamic representation), that is specific to the information-link of digital twins (steering representation), and that is specific to the digital model of digital twins (*in silico* representation).

The idea of scientific representation leads to control

The idea of scientific representation leads to instrumentations of digital twins as technology of control. This point can be derived from Deleuze's discussions on science and will become more clear over the course of the chapter. For now I will explain it shortly. A representational understanding of scientific knowledge leads to a focus on identity and resemblance and because of that develops a desire for a unified understanding of reality. This unification leads to the reduction of (scientific) knowledge to a single logic and dismantles the creativity of science (Deleuze & Guattari, 1994; Jensen, 2018; Stengers, 2010). Explanatory and predictive power (accuracy) become benchmarks for measuring legitimacy of representations and simulations. This mechanism of legitimation leads to an instrumentalisation of digital twins as a technology of control.

To conclude, there is a need for an empirical account of digital twins that could form the starting point of a unified understanding of digital twins that does not make one component more important that the other components and that is not "traced" to the idea of scientific representation as that leads to instrumentations as a technology of control.

An alternative empirical account of digital twins

This section serves to goal to develop an empirical account of digital twins that could form the starting point of a unified understanding of digital twins. As discussed in the general introduction, transcendental empiricism draws attention to the differences (events) that condition the form that a phenomenon takes on. To develop a concept we should not concern ourselves with what something is or what it is not, rather we should ask ourself questions like "who? how? how much? where and

concepts to be of use; this moment is called the synthesis. The problem with this, according to Bergson, is that the conceptualisations that are formed are inaccurate as they are only approximated based on the interactions between the thesis and anti-thesis (Deleuze, 1988, p. 46-47). Moreover, the positive (thesis) and the negative (anti-thesis) are not approached as two different concepts, but they are considered to be two of the same kind only differing in degree (Deleuze, 1988, p. 46).

when? in what case?" (Deleuze, 1967, p. 92). The empirical account of digital twins that is developed below explains the emergence of digital twins by the difference that digital twins are concerned with real-world phenomena rather than experimentally produced phenomena.

The difference: Experimentally produced phenomena VS Real-world phenomena

Digital twins exist of digital models that are supported by a data-information link. With digital models I refer to representations that are constructed using computers and that are supposedly 'run' on computers to perform simulations (Winsberg, 2019). Digital models are generally used to study phenomena for which little data is available or access to data is difficult due to practical or ethical reasons. They are supposed to fulfil three purposes: to help understand a phenomenon, to predict behaviour of a phenomenon, and to communicate insights and predictions (Winsberg, 2019). To get this done, digital models integrate existing principles, theories and models into each other to create a model that matches with the phenomenon of interest. In order for a digital model to match with a phenomenon, care must be taken to ensure that the conditions underlying the model and that make up the phenomenon are align. Conditions refer to variables that define a situation, such as temperatures, materials, structures etc.

In a laboratory context it is possible to strongly regulate the conditions under which a phenomenon occurs. This is done under the guise of reproducibility. However because of this strict regulation, can the phenomena that are produced hardly be considered 'real-world' phenomena. As a result, the models and explanations that are based on experimentally produced phenomena are not directly applicable to real-world phenomena as experimentally produced phenomena are highly simplified (Cartwright, 1983). Weinbaum (2015) points out that in science, phenomena are often understood as a black box with a distinct 'inside' and 'outside', a stable causal structure on the inside, and a stable stream of 'inputs' and 'outputs'. Real-world phenomena, however, do not have rigid boundaries, do not have stable causal structures and do not have a steady stream of inputs and outputs. Real-world phenomena are generally way more complex and 'messy' than the phenomena produced in laboratories. Moreover, real-world phenomena often include multiple phenomena that interact with each other. This makes the modelling of real-world phenomena significantly more difficult. Digital twinning should be understood as a method to overcome the difficulties that are run into with modelling real-world phenomena.

Modelling real-world phenomena

According to Wilson (2017), the main strategy for modelling real-world phenomena is to adopt a pragmatic attitude which means to only model those parts of phenomena that you need an explanation of and simplify the model as much as possible. Simplification is done by focussing on

dominant behaviour and dividing the phenomenon into sub-phenomena and approach them as individual modelling problems (Wilson, 2017). In other words, the main strategy is to look for stable black-boxes. Wilson (2017) refers to these pragmatic modelling techniques as strategies of "physics avoidance". These strategies make the modelling problem more graspable which helps to avoid errors. Moreover, it also limits the computational burden and allows for applying existing knowledge (models) to the problem at hand (Wilson, 2017).

Real-world phenomena often transpire across multiple size scales and the processes of these different scales can hold relations to each other that determine each other's behaviour (Bursten, 2021). A phenomenon may for instance include processes that happen at organ, cellular and molecular level, where the processes on cellular level have consequences for the processes on molecular level which then again influence processes on the organ level. The reasoning that unifies the different scales to a coherent whole is informed by empirical observations that can involve complex mechanisms. These reasonings hold a back-and-forth logic rather than purely bottom-up or top-down reasoning (Wilson, 2017). In modelling, these mechanisms are often reduced to a homogenised form that can be used to communicate between all the different scales of the phenomenon. This is referred to as homogenisation (Wilson, 2017). In sum, a model of a real-world phenomenon can be schematised as a fragmented web of black-boxes spanning multiple size scales that are connected through homogenised information flows.

So, what does a data-information link actually add here? Although phenomena are schematised as stable black-boxes, in reality this is not the case. As Weinbaum (2015) points out, real-world phenomena are messy, input and boundary conditions change even if the internal structure of a phenomena itself is stable. However, these changes cannot be captured in the mathematical equations of models because they fall outside the black-box. Changes in input and boundary conditions of the real-world phenomenon are continuously passed on to the model via the data-link so that the model remains up-to-date. Where data-links provide an explanation of the trajectory of a phenomenon up to the present moment, information-links attempt to determine the trajectory of a phenomenon in the present and the future.

When one decides to act based on the information that a model provides about the behaviour of a phenomenon and this action intentionally affects the phenomenon of interest, then we can speak of an information-link between the digital twin and the physical phenomenon. Although it is likely that there will be acted on the information that a digital twin produces, it is not necessary the case that the action will affect the physical counterpart of the digital model. For example, a weather model predicts that it will be raining, hence I bring an umbrella. Me bringing an umbrella, however, does

not affect the weather. Moreover, the action that affects the real-world phenomenon should also be intentional, meaning that it is motivated by the information that the digital model provides, otherwise the action should be considered part of the regular behaviour of the phenomenon. For this it is not important whether the action causes the intended outcome. The information-link can be used as a means to limit the degrees of freedom of a phenomenon, consequently, based on insights from simulations are information-links used to problematise certain states of the phenomena of interest and idealises other states. In literature on digital twins has been speculated about the possibility to automate information-links by use of robotisation (Ortt & Tiihonen, 2022).

Case study: Airframe digital twin

To gain a better understanding of the internal structure and aspects of a digital twin, consider the following case of a digital twin of an aircraft described by Tuegel et al. (2011). The digital twin is supposed to provide insight into the life expectancy of the airframe (the metal structure and plate work) of the vehicle. What this digital twin comes down to is that it intends to provide a representation and a prognosis of the behaviour of the physical (real-world) airframe in order to assess and prolong the airworthiness of the aircraft. The schematisation of the digital twin by Tuegel et al. (2011) is visible in figure 3.

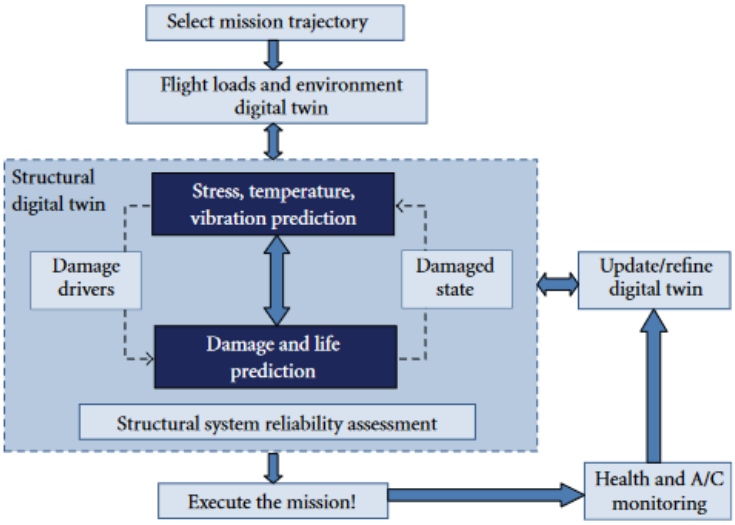

Figure 3: Schematisation of airframe digital twin by Tuegel et al. (2011).

The digital twin determines the airworthiness of the aircraft based on the amount of damage to the airframe. Damage to the airframe comes in various forms:

> "Damage is not limited to fatigue cracking, but includes creep, fretting and wear, delamination and microcracking in composite materials, corrosion and oxidation, and panel buckling among others." (Tuegel et al., 2011, p. 3)

Damage is caused and develops further by various phenomena that occur across multiple scales. For example, aerodynamic heating and aerodynamic pressure that occur during the flying of the aircraft affect the internal stresses in the structure of the airframe and its components. These stresses in turn affect phenomena at the lower level of the material scale. The digital twin therefore includes various sub models.

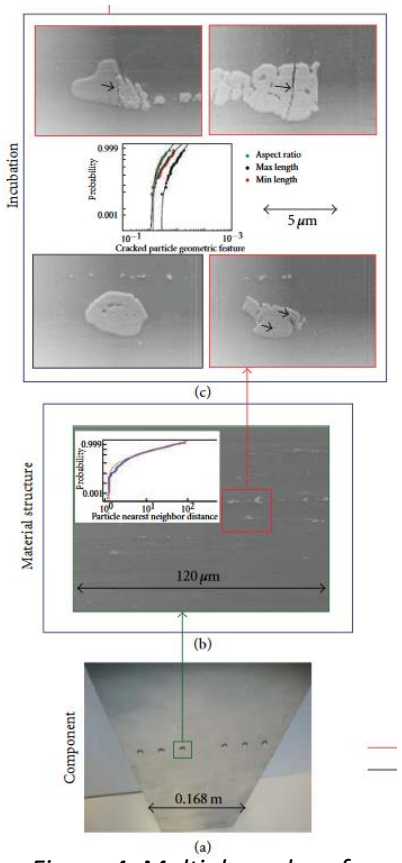

Figure 4: Multiple scales of material by Tuegel et al. (2011).

Digital model

At the material level, for instance, is the model divided into multiple sub-phenomena at different scales (see figure 4). The information that is transferred top-down between the scales is mainly topological in the sense that it provides a location and the periphery for the phenomena on the lower scale – so called "hot-spots" or points of damage (Tuegel et al., 2011, p. 7). This topological information informs about the boundaries of phenomena (the boundary conditions). Other information that is transferred is input data for phenomena. For the material scale is this for example the stress data that has been calculated earlier on the structural scale. In the case is information continuously send back-and-forth between models on different scales (structure, component, material) (Tuegel et al., 2011).

Data-information link

The information that is communicated between different scales about the boundary and input conditions (but also initial conditions with evolutionary phenomena such as crack growth) does not merely stem from the equations of other sub-models but stems from empirical observations as well (such as with material deformation) (Tuegel et al., 2011). In the case is data about usage (fight trajectory and loading data), environment (weather, humidity, etc.), geometry (shape of components) and boundary conditions (damage hot-spots) manually as well as autonomously gathered and inserted into the airframe digital twin. This data is used to eliminate "uncertainties in boundary conditions, geometry, usage, and environment" (Tuegel et al., 2011, p. 7) which are changes that fall outside the models of the digital twin as they remain indetermined until the event of change has passed. This process can be considered the data-link. There is also an information-link in the case study. Based on insights provided by the digital model that makes use of the data provided by the data-link are actions

performed in such a way that the airframe suffers as little damage as possible and crack growth is limited. This is for instance done by loading the aircraft in a particular way, avoiding certain flight manoeuvres, and avoiding environments with extreme weather conditions.

In short, digital twins can be schematised as a fragmented web of unstable black-boxes spanning multiple size scales that are connected to each other by simplified relations which are based on mechanical explanations grounded in empirical observations. The black-boxes – sub-phenomena – are unstable because real-world phenomena include uncertain elements that cannot be captured in mathematical equations. Therefore digital twins require a data-link to determine those elements in retrospect and insert them in the digital model. Based on the sights of the digital model is an information-link used to inform actions that affect the phenomena of interests so that they affect the phenomena in a desirable way.

Conceptualising the empirical account

This section develops a conceptual framework for digital twins based on the empirical account constructed above. For this will be made use of the metaphysical ideas of Deleuze. As will be discussed, Deleuze's metaphysics emphasises the creative potentiality of life and centralises change by directing its attention to processes, difference, and becoming rather than on identity, resemblance and being. For this reason are Deleuze's ideas chosen as the conceptual framework to foster the instrumentalisation of digital twins as technologies of transformation. The conceptualisation of the empirical account is executed in the following steps: First, is the experience of real-world phenomena conceptualised by the concepts clear-confused perception and distinct-obscure ideas. This conceptualisation explains the need of a data-link in digital twins. Second, is the emergence – the genesis – of the experience of real-world phenomena explained by use of Deleuze's metaphysics. Third, Deleuze's notion of idea is further investigated in order to explain the genesis of the internal structure of digital twins and how, despite their fragmented structure, they still account for parts of experiences of real-world phenomena. In addition, it is nuanced how experiences of control and oppression arise through the use of digital twins and what role the information-link plays in this.

Conceptualising indeterminacy in real-world phenomena

Clear-confused perception and distinct-obscure ideas

The way real-world phenomena are experienced during modelling practices, as distinct regions with uncertain boundary, initial, and input conditions, is remarkably captured by Leibniz's concept of clear-confused perception. Gilles Deleuze (1994) develops this concept further and it is his interpretation that will be discussed.

Leibniz describes the clear-confused with the following quote:

> "To give a clearer example of these minute perceptions which we are unable to pick out from the crowd, I like to use the example of the roaring noise of the sea which impresses itself on us when we are standing on the shore. To hear this noise as we do, we must hear the parts which make up this whole, that is the noise of each wave, although each of these little noises makes itself known only when combined confusedly with all the others, and would not be noticed if the wave which made it were by itself." (Leibniz, 1996, p. 54)

In this example is the-noise-of-the-sea the real-world phenomenon that is experienced, which is a clear distinguishable phenomenon. Same as with the example of the airframe can the-noise-of-the-sea be subdivided in parts: little noises of each wave. However, these little noises are indistinguishable in the greater noise of the sea. They form a confused whole as the boundaries of each little noise cannot be distinguished. The concept of clear-confused draws attention to the fact that in our perceptual experiences some parts are clearly expressed, while other parts remain confused. The clear, Deleuze argues, refers to an actual state of affairs that could be considered determined (and that therefore could be captured in an equation). The confused refers to a virtual flux that in potential is determinable but currently is indetermined. Reality, Deleuze (1994) argues, consists of both the actual and the virtual where the actual refers to that what exists – what is experienced – and the virtual to that what does not exist – what is not experienced. Next to the empirical part of experience is there also a transcendental part that is concerned with the experience of ideas. According to Deleuze (1994), ideas are experienced as distinct-obscure. The distinct refers to the part of an idea that is actual as it expresses a coherent determined whole, e.g. the idea of a wave. The obscure refers to indetermined parts of an idea that remain virtual (Deleuze, 1994). The parts of the idea of a wave that remain obscure are for instance those parts that allow to distinguish individual waves in the greater noise of the sea.

These two conceptualisations of the experience of perceptions and ideas provide an explanation for the difference in experience between real-world phenomena and experimentally produced phenomena. Experience not only exists of stable (determined) elements but it also includes elements that are in a state of change, in an indeterminate flux. In fact, as will become clear later, the elements that come across as stable are also changing but in a less intense manner. Phenomena that are produced in a laboratory setting are kept stable by controlling the conditions (boundary, initial, input) that determine the phenomena, as a result, these phenomena do not contain virtual elements. The phenomena only appear as clear and distinct. When modelling real-world phenomena this is no longer the case as phenomena are no longer stable black-boxes but they also include virtual

elements which cause perception to be confused and ideas to be obscure. Real-world phenomena are creative and indeterminate. Only actual elements – elements that are clear and distinct – can be captured in mathematical equations. It is therefore that elements that are subjected to lots of change, such as boundary conditions, initial conditions and input conditions, can only be determined through empirical observations. The data-link of digital twins is used to register a perception as soon as it becomes clear. The case of the airframe digital twin demonstrates this in the fact that topological location of cracks in the airframe (boundary conditions) and the aerodynamic forces causing pressure and heating (input conditions) cannot be captured in a mathematical equation, but rely on empirical observations.

Deleuze's metaphysics

According to Deleuze (1994), reality is creative and is in a constant process of becoming. Building on the assumption that reality is only accessible through experience (Baugh, 1993), for Deleuze, the coming into being (existence) of things is the same as the coming into experience of things through perception. It is true that things can come into being without an observer experiencing them, but we cannot say anything about these things, we cannot even think about them because we have no idea of them. The observer itself goes through a process of becoming as well. This process is experienced as perception becoming more clear and ideas becoming more distinct, hence Deleuze understands the process of becoming as processes of becoming sensible. Deleuze's metaphysics is concerned with explaining this process.

The account discussed below only provides an explanation of a single process of becoming, but it is important to keep in mind that this is happening with every thing and with every one. Moreover, the process of becoming sensible is not only limited to humans and organisms. A liver, for example, becomes sensible to alcohol and starts to die off. For an observer, these changes remain virtual at first and only become actual when he feels a twinge in his stomach, goes to the doctor, has himself examined, and is told that his liver is not doing well. The process of becoming, becoming sensible, refers to both physical processes as well as cognitive processes (Deleuze, 1994). For the observer has the idea of his dying liver gone from the obscure to the distinct, consequently, the observer is reminded of the idea of his dying liver with every twinge in his stomach.

The actual and the virtual

Before I go into the process of becoming, which Deleuze (1994) refers to as actualisation, I will first

elaborate on the ontological distinction between the actual and the virtual[3] that causes perception to be clear-confused and ideas to be distinct-obscure.

The ontological distinction between the actual and the virtual centralises the changing nature of experience and is therefore based on difference rather than identity. Deleuze replaces identity as a way for defining substances with difference. With this move towards difference, Deleuze renounces essence-based ontologies that approach substances on the bases of resemblance to an idealised identity (Smith, 2007). Deleuze argues that things are defined – gain their identity – by the conditions in which they find themselves. This, in the sense that an answer is determined by a question and a solution is determined by a problem. Conditions answer to questions such as: "who? how? how much? where and when? in what case?" (Deleuze, 1967, p. 92). These questions inform us about the differences between things; the differential relations that determine things reciprocally (Deleuze, 1994). For example, two marbles identical in colour and size are still distinguishable as they both have a different spatial-temporal relationship to each other and to their observer.

An idea in the actual is made up of clearly observable spatial extensions that are arranged by distinct qualities (identities) (Borum, 2017). For instance, in the discussed digital twin case is the aircraft a quality and are the parts its spatial extensions. Qualities come across as stable entities performing determined behaviours. However, as mentioned, qualities are not stable, and their behaviour is not determined. Qualities (identities) are in constant processes of change Deleuze argues, as a result, we should not speak of being but of becoming (Weinbaum, 2015). The virtual is an indeterminate flux of

[3] Deleuze adopts the distinction between the actual and the virtual from the work of Henri Bergson (Deleuze, 1988). Bergson develops the two concepts in response to the Kantian distinction for existence and non-existence: the real and the possible, which he rejects for being based on the false assumption that possibility precedes reality (Deleuze, 1988; Smith, 2009). If we say that the possible resides the pre-existing, then it seems common sense to assume that the real – that what exists – comes after the possible. Because of this assumption is possibility considered to be something 'less' than reality. According to Bergson, this is a mistake, because reality in fact precedes possibility, making the possible 'more' than the real (Deleuze, 1988, p. 17). The confusion of the 'more' and the 'less', as Bergson (Deleuze, 1988) calls it, is a common mistake that originates from the method that is used for defining concepts, that of negation (see footnote 2). Negation defines concepts by what it is not (Horn & Wansing, 2022). The real is that what exists, the possible is that what not-exists. Bergson states that the negated concept (the possible in this case) is considered to be 'less' than its counterpart, while actually it is something 'more'. Bergson schematises this as follows; the possible is 'more' because, alongside a general notion of the real, it also contains the act of negation and a motive for that negation (Deleuze, 1988a, p. 17). Moreover, because negation defines a concept by another concept, the difference between these concepts is only a matter of degree (Deleuze, 1988). The concept and its negation thus appear as two sides of the same thing. Negation is therefore unable to install an ontological distinction between concepts (*difference in kind* as Bergson calls it). For the concepts the real and the possible, this is a problem because it would mean that the relation between existence and not-existence is a scale, meaning that things can also *exist a little* or *almost exist*. Bergson is convinced that existence is absolute; something either exists or not (Deleuze, 1988). It is therefore that Bergson develops conceptions of existence and non-existence that stand on their own and are truly different in kind. That what exists Bergson calls the actual and that what not exists he names the virtual.

differential elements that do not (yet) hold relations to each other (Deleuze, 1994). These elements are 'pure differences' in themselves. Deleuze's concept of the virtual idea is based on a notion of difference that stands on its own instead of relying on others to be defined (Smith, 2007). When ideas become actual, differential relations reciprocally determine each other. Because the differential elements of the virtual do not hold relations among each other, they cannot be quantified or qualified (DeLanda, 2005, p. 74) which explains the inability to capture virtual elements (e.g. boundary conditions) in mathematical functions.

Actualisation

According to Deleuze (1994), the process of becoming can be understood as the moving of an idea from the virtual (the obscure) to the actual (the clear). This process which Deleuze (1994) calls actualisation is a process of determination of that happens by two processes: differen*t*iation and differen*c*iation (Deleuze, 1994).

The process of differen*t*iation transforms the virtual flux of differential elements into fully determined virtual ideas (Deleuze, 1967). This happens in two steps: First, relations are established between the differential elements through which elements become 'reciprocally determined', these relations are referred to as differential relations (Smith, 2007). Secondly, virtual ideas are fully determined when points are established in the middle of differential relations. These points are points of pure difference and are called singularities (Clisby, 2015). Singularities are properties of matter that are not divisible, such as velocity, temperature, chemical concentration, pressure etc. and are in contrast with properties that are divisible like mass, area, electric charge, volume etc. (Weinbaum, 2015, p. 8). Differences in such singularities can only be expressed in relation to something else, hence they are intensive differences. After these two steps is a virtual idea fully determined which means that it contains a sufficient reason that keeps its elements together (1967). When a virtual idea is determined by a sufficient reason it is differenciated in spatio-temporal extensions and qualities (Deleuze, 1967). It is by this that they gain an actual (spatial) dimension. As mentioned, Deleuze substitutes being for becoming and renounces essence-based ontologies that assume stability. The qualities (identities) that are actualised are inherently unstable and only reflect the idea in a singular way. Ideas can namely be actualised in a manifold of ways each being a full-fledged identity. This for the reason that ideas are multiplicities.

The concept multiplicity reconciles heterogeneity and continuity and forms an alternative to the concept of unity (Deleuze, 1988, p. 43). With the concept unity, being one means being uniform and being singular (Deleuze, 1988, p. 44). With multiplicity, however, being one means being different and being multiple. A virtual idea is a multiplicity that contains many differential relations and

singularities which could be determined in a multitude of ways. An actualisation of an idea only embodies a select part of the virtual idea. The determination of virtual ideas – through differen*ciation* – is driven by intensive differences that occur in the milieu in where phenomena find themselves in (Deleuze, 1967). This determination goes progressively, meaning that the identity of a phenomenon changes and that the phenomenon not is, but becomes (Weinbaum, 2015). Due to the vastness of the multiplicity of the virtual ideas and the fact that its differential relations and singularities are concealed, are actualisations "unanticipated processes of becoming" (Rölli, 2009, p. 49).

Intensive differences are differences in properties of matter that are not divisible and that express a sensible effect (Weinbaum, 2015). The difference between differential relations and intensive differences is that differential relations remain virtual and that intensive differences are actual and can therefore be sensed (Deleuze, 1994). Intensive differences are produced by the milieu in which an individual finds itself. This milieu is itself actualising – or individuating: becoming an individual (Rölli, 2009). Intensive differences determine the actualisation of individuals by which they are sensed, examples are "differences in scarcity or abundance of a resource can drive economic processes; differences in distributions of predators and prey within food chains can drive ecological and evolutionary processes; differences of demographic distributions within a population can drive social processes; genetic differences within populations can drive phenotypic adaptation processes" (Weinbaum, 2015, p. 8). Differential relations remain virtual unless they are intensified by a sufficient reason (Williams, 2009). Sufficient reason will be discussed in more detail below.

The notions of the actual, the virtual, and actualisation provide us with an explanation of the indeterminate nature of real-world phenomena and the need for digital twins to have a data-link to determine virtual elements (boundary, initial and input conditions) in retrospect (when they have become actual). However, as discussed the structure of digital twins is more complex: digital twins take the form of a fragmented web of sub-models that is assembled into a whole by a logic derived from experiences of the phenomenon. To gain a better understanding of the process of becoming and how the structure of digital twins emerges we have to take a closer look at Deleuze's notion of the idea.

The genesis of the internal structure of digital twins

As discussed, digital twins are buildup out of a web of fragmented sub-phenomena that are connected to each other in a simplified, homogeneous way that is not based on a principled reason (e.g. bottom-up or top-down). The homogenisation is based on empirical observations about the mechanisms that span across multiple layers. The sub-phenomena of a digital twin are being bundled

to a coherent whole that has a homogeneous logic. This logic is however not made explicit in scientific functions of the digital twin but remains implicit, stemming from practical and intuitive considerations, as Wilson states:

> "The outputs of multiscalar modelings supply mixed-level explanations in the sense that their descriptive architectures generally stem from direct empirical observation of the manner in which various [...] scales causally affect one another within a complicated material. We don't pretend to have "derived" these empirical hierarchies from molecular fundamentals; we instead exploit our direct knowledge of physical layering to better computational advantage." (Wilson, 2017, p. 24)

Ideas as events

Deleuze refers to the logic that connects together the sub-models of a digital twin as "sufficient reason" (Deleuze, 1994). A sufficient reason binds together the fragmented pieces of scientific knowledge – actualised state of affairs – to a collective duration. A duration is the experience of the present moment which is experienced as a coherent whole. According to Deleuze, as science progresses it actualises more state of affairs as part of the same duration which causes the duration to contract. When a duration becomes more contracted "the physical system obtains more and more variables, spatial relations within it prove to be endlessly divisible, and the photo is snapped with ever greater resolution and detail" (Gaffney, 2010, p. 108). The contraction of a duration by actualisation can go on infinitely since the sufficient reason that holds it together stems from a multiplicity; contraction is namely the actualisation of a virtual idea (Gaffney, 2010). Ideas can also be understood as events (Williams, 2009). An event is a moment of change, and as I just mentioned the unrolling of this change can go on forever. An event is an ever during present – a duration – which only ends when it is replaced by another event. It is therefore that Deleuze does not speak of being in the world or discovering the world but of becoming the world, as an idea (event) progressively becomes actualised. Through actualisation becomes an idea (event) more distinct and perception less confused as it unrolls the event by the actualisation of states of affairs.

Reflection on digital twins as technology of control

In sum, experience is determined by the ideas that an observer holds. Although these ideas are multiplicities, the observer is only experiencing a particular differen*t*iation of the idea which causes the idea to be experience along a single sufficient reason. This sufficient reason determines what differences are intensive differences meaning that it decides what changes to the phenomena of interest are sensible for the observer. Put differently, what differences get to be actualised. The differences that remain unintensified by the sufficient reason are not experience by the observer. In

short, the sufficient reason determines which parts of an ideas are distinct and which are obscure and which perceptions are clear and which are confused.

The structure of digital twins emerges as fragmented because scientific modelling is only concerned with those elements that are experienced as stable; science is only concerned with state of affairs. Experience, however, includes more than just stable elements, experience also includes elements that are in a state of change; that are changing. These are experienced as an indeterminate flux such as boundary conditions, initial conditions, and input conditions. Because the models of digital twins are unable to capture indeterminate elements, digital twins make use of data-links to register a perception as soon as it becomes clear. Or put differently, when an intensive difference becomes actual. A data-link can only respectively register an actualisation; in the moment of indeterminacy – in the event – things are confused. With help of the data-link is a particular sufficient reason, a particular becoming of the phenomena of interested, affirmed. This sufficient reason arises from the modelling process, where the relations between the sub-models of a digital model are based on the modeller's personal experience of the phenomenon and practical considerations (Wilson, 2017). This sufficient reason does not change during the digital twinning process. The actualisation of phenomena along a sufficient reason is determined by the intensive differences that are produced by the environment that they are in. Because users of digital twins hold an ideal of how they desire an phenomenon to be, digital twins make use of information-links to steer phenomena in a desired trajectory by cancelling out (potential) intensive differences that could be produced by the environments that the phenomenon is in. Refer back to the airplane case study, an example of this could be to avoid extreme weather conditions. To conclude, digital twinning that lead to experiences of control can be understood as a method for regulating the course of becoming of a phenomenon.

The genesis of experiences of oppression and control

Deleuze points out that when an idea is actualised, when it is differenciated along a sufficient reason, we do not experience the idea as a multiplicity and we forget that ideas can be determined by multiple sufficient reasons. Moreover, it cannot be assumed that people hold exactly the same sufficient reason along which a phenomenon is actualised. A phenomena is experienced differently by everyone. The sufficient reason on which a digital twin is based – the way it actualises the phenomena – is likely to be different than the sufficient reason that someone other than the modeller holds. There are three issues with this in current practices of digital twinning that lead to experiences of oppression and control.

The first issues is that when the digital twin is used out of a position of power, the sufficient reason oppresses alternative sufficient reasons of the idea. The second issue, for which is frequently warned

in STS literature, is that the sufficient reason of a digital twin is simply adopted by everyone and that the virtual idea is only experienced in a singular way instead of as a multiplicity. This process is referred to as singularisation, hence the conceptualisation of digital twins as "technology of singularization" (Turnhout & Lynch, 2024, p. 3). Furthermore, singularisation also has the result that marginal sufficient reasons become even more marginal and end up in an even greater disproportionate power relation, leading to a greater experience of oppression. Thirdly, what further contributes to the experience of control is that digital twins use an information-link that cancels out unwanted potential intensive differences. These intensive differences might have been valuable for other sufficient reasons. As a result, is not only the transcendental experience oppressed, but so is the physical milieu that produces the intensive differences that actualise the idea along your sufficient reason. A possible consequence of the information-link of digital twins is thus that a milieu no longer supports alternative (marginal) sufficient reasons as the intensive differences they requires are cancelled out.

It is the desire to contract a duration that causes these oppressive experiences. Durations get to be contracted by actualisation. Through actualisation becomes an idea (event) more distinct and perception less confused as it unrolls the event by the actualisation of states of affairs. As a result, the experienced duration is more predictable and better explainable. The epistemic values of explainability and predictability are commonly used as standards to assess the quality of digital twins. This stimulates the use and further actualisation of already existing sufficient reasons. This results in the increase of the hegemony of the already hegemonic sufficient reasons, which causes the power relations to only become more skewed and digital twins become more and more technologies of control. The mechanism of legitimation that is currently used for digital twins, that is predictive and explanatory power, has to be substituted for digital twins to be used differently than a technology of control. What Deleuze draws attention to with his philosophy is that science is not just a means to actualise an idea along a sufficient reason but that it is also a way to develop new sufficient reasons (Stengers, 2010). As an example of this refers Deleuze to Kuhn's paradigms (Deleuze & Guattari, 1994). The method that Deleuze proposes for this would form a good foundation for a mechanism of legitimation that supports the instrumentalisation of digital twins as technologies of transformation. This is the subject of investigation of chapter 2.

Conclusion

In literature in the philosophy of technology and science and technology studies (STS) are concerns raised that digital twins are used as a technology of control (Helbing & Sánchez-Vaquerizo, 2023; Kloppenburg et al., 2022; Turnhout & Lynch, 2024). This chapter argues that the way digital twins are used gets to be determined by the way they are understood. Therefore, to eliminate the instrumentalisation of digital twins as a technology of control, the current conceptual framework that explains digital twins needs to be replaced. As discussed in the general introduction, a desirable instrumentalisation of digital twins would be as a technology of transformation. Consequently, the chapter is concerned with answering the question: *What could be a conceptual framework for digital twins that would enable them to be used as a technology of transformation?*

This question is answered in three steps that are based on Deleuze's transcendental empiricism. First, are existing conceptions of digital twins that lead to the instrumentalisation as technology of control dissected. From this is concluded that existing conceptions of digital twins are derived from the transcendental idea of scientific representation and are empirically grounded only in a specific component of digital twins. This creates the need for a conceptual framework for digital twins that is grounded in a unified empirical account of digital twins and that is not "traced" to the idea of scientific representation as that leads to instrumentations as a technology of control.

Second, is a unified empirical account of digital twins developed. This account explains the emergence of digital twins by the difference that digital twins are concerned with real-world phenomena instead of experimentally produced phenomena. By use of a case study are digital twins eventually schematised as a fragmented web of unstable black-boxes spanning multiple size scales that are connected to each other by simplified relations which are based on mechanical explanations grounded in empirical observations. This fragmented web of unstable black-boxes (the digital model) is supported by a data-link that retrospectively determines unstable elements such as boundary conditions, initial conditions, and input conditions and inserts these elements into the digital model. Based on the sights of the digital model is an information-link used to inform actions that affect the phenomena of interests so that they affect the phenomena in a desirable way.

Third, based on the newly developed empirical account of digital twins is a conceptual framework developed for digital twins that is grounded in Gilles Deleuze's metaphysics. This metaphysics forms a good basis for digital twins to be instrumentalised as technology of transformation because it emphasises the creative potentiality of reality and centralises change. By use of the newly

constructed conceptual framework is an understanding developed of the current instrumentalisation of digital twins a technology of control.

Current practices of digital twinning that lead to experiences of control further actualise an idea along an existing sufficient reason and try to regulate the course of actualisation of that idea by cancelling out potential intensive differences. By the further actualisation of an idea, the idea gains legitimacy as the duration that is experienced gets to be contracted. This results in the experience of an increase in predictive and explanatory power; the model that is considered to be a representation of a phenomenon is experienced as accurate. By use of Deleuze's ideas is demonstrated that it is the mechanism of legitimacy that is currently used for digital twins that leads to situations of oppression and control. This mechanism should not be based on predictive and explanatory power, because this leads the further actualisation of hegemonic sufficient reasons. A different mechanism of legitimation could open up the possibility to use digital twins differently, potentially as a technology of transformation. Therefore, by use of the in this chapter presented conceptual framework investigates chapter 2 a mechanism of legitimation that supports the instrumentalisation of digital twins as technologies of transformation.

Chapter 2: **On the possibility of digital twins as technology of transformation**

Introduction

Chapter 1 establishes that the mechanism by which digital twins are legitimised is leading to the instrumentalisation of digital twins as technology of control. Replacing this mechanism could lead to a different instrumentalisation of digital twins. Consequently, this chapter is concerned with developing a legitimation mechanism that could lead to the instrumentalisation of digital twins as technology of transformation. The chapter addresses the question: *What could be a legitimation mechanism for digital twins as technology of transformation?*

The chapter addresses this question by developing a legitimation mechanism for digital twins as technology of transformation by use of the Bergsonian notions of true and false problems which Deleuze adopts in his work. This mechanism is further nuanced with the help of John Dewey's theory of intelligent conduct. Dewey's theory is used to gain an understanding of the possibility of action while being in an event; in a moment of change. Dewey's theory is thus used to nuance the ideas of Deleuze, simultaneously enrich Deleuze's ideas the work of Dewey because they position it in a larger context. Lastly, explores the chapter how the developed legitimation mechanism could become part of practices of digital twinning.

Intensification as a legitimation mechanism

This section develops a conception of a legitimation mechanism for digital twins as technology of transformation. This will be done by use of the Bergsonian notions of true and false problems which Deleuze adopts in his work (Deleuze, 1988; 1994). The notions true and false problems allow to make a distinction between digital twins being used as a technology of control and digital twins being used as a technology of transformation, namely technologies of control regulate the course of a becoming of a phenomenon and technologies of transformation propose a new becoming for a phenomenon.

True and false problems

Following Deleuze (1994), it can be argued that to use digital twins as a technology of control leads to false problems. False problems appear when state of affairs are problematised rather than the ideas (sufficient reasons) that actualised those state of affairs (Deleuze, 1994). When a state of affairs is problematised, an individual tries to solve the problem by substituting the state of affairs for another one. Since the sufficient reason forms the conditions out of which the problematic state of affairs emerges, the sufficient reason is problematic as well. The alternative state of affairs that is

considered the solution however remains within the boundaries of the sufficient reason. It is therefore that Deleuze considers the mere problematisation of a state of affairs to be false problematisation, because it does not focus on what is problematic, but only on an effect of it (Deleuze, 1988). Proper problematisation, a true problem, is therefore concerned with replacing the sufficient reason that actualised the problematic state of affairs.

True problematisation is about transformation: by substituting the sufficient reason of an idea with a new one, the becoming of the phenomenon is transformed. True problematisation is the problematisation of an event (idea) and false problematisation is the problematisation of a state of affairs (actualisation). As discussed in chapter 1, an event is a moment of change which unrolls by the actualisation of states of affairs. This unrolling can go on forever and is experienced by the contraction of a duration (Deleuze, 1988). An event only ends when it is replaced by another event. Through actualisation becomes an idea (event) more distinct and perception less confused as it unrolls the event by the actualisation of states of affairs. This demonstrates the order in which true and false problematisation proceed: an idea (event) first needs to become distinct and clear by means of actualisation (false problematisation) before it can be problematised and substituted. False problems thus come before true problems and are supposed to create the conditions where true problematisation is possible.

The question is, how? How can false problematisation create the conditions under which true problematisation can occur? As discussed in chapter 1, virtual ideas emerge from a process of differen*t*iation and are made up of differential relations and singularities. For differen*c*iation (actualisation) to occur, an individual[4] needs to come in contact with a milieu that produces intensive differences. The individual experiences an intensive difference as an event; a moment of change; as a moment of difference. The experience of an event does not trigger the actualisation of a virtual idea, "but rather the thinking of it" (Rölli, 2009, p. 50). This can be explained as follows: Every individual exists of a field of intensity that includes the intensive differences to which the individual is sensible (Rölli, 2009). The field of intensity determines the virtual ideas that are actual to the individual. An event – the experience of an intensive difference – causes a flux in the intensive field of the individual which forces the individual to think (Williams, 2009). It is this thinking process in current practices of digital twinning that results in false problems.

[4] Deleuze not only refers to persons as individuals but to all systems that respond to intensive differences. The airframe discussed in chapter 1 therefore also applies as an individual. However, not all individuals have like persons the capacity to think (Deleuze & Guattari, 1984).

Figure 5: Evolution of aircraft cockpits (deHav88, 2014).

Intensification as a mechanism of legitimation

By being in contact with a milieu – a real-world phenomenon that produces intensive differences – an individual becomes sensible to more and more intensive differences. This is called intensification. Intensification is necessary to be able to construct true problems and thus for the transformation of sufficient reasons. Therefore, is intensification proposed as the legitimation mechanism for digital twins of transformation.

The need for predictive and explanatory power

Being intensified – susceptible to lots of events – is not necessarily a pleasant condition to be in. Imagine flying in one of the first aircrafts and having to deal with all the intensive differences that come with flying a plane. It required an huge amount of skill to keep an aircraft in the air and every event that happened to the plane required a response. When we look at the evolution of aircraft cockpits (see figure 5), the process of intensification (becoming aware of intensive differences) that has occurred is visible by the increase in the number of meters that inform the pilot about possible intensive differences affecting the aircraft. Moreover, there is currently a trend towards handing over the awareness of intensive differences to technological tools such as an autopilot. By use of false problems we are able to stabilise a milieu so that it becomes bearable for an individual to be part of (Leistert & Schrickel, 2020). This gives the individual the opportunity to intensify.

Increasing the predictive and explanatory power over a phenomenon by contracting a duration is thus beneficial for intensification as it helps to prevent harm to those involved with the phenomenon. However, the contraction should not limit the individual in intensifying itself as this would eliminate the opportunity to transform a sufficient reason. To gain a better understanding of the relationship between contraction and intensification will the next section go into the experience of being in an event; of being in a moment of change. It is in a moment of change that individuals can intensify, though it is also when they can get harmed. John Dewey's theory of intelligent conduct will be used to navigate this experience.

Intelligent conduct as a method for dealing with the event

John Dewey's theory of intelligent conduct (Dewey, 1922a) belongs to a pragmatist account on

human conduct. According to Dewey, human conduct can be divided into three categories: impulse, habit and intelligent (Dewey, 1922a). Impulse is a conduct that is not concerned with the consequences of an action. It is unreflective and goes by instinct and reflex. Habits are impulses that are directed towards an outcome that is specific to a situation and that are socially determined. An example would be the habit of eating cake on a birthday, here the impulse to eat is given direction (what to eat, when to eat, how much to eat). Intelligent conduct is required when a person finds itself in a situation where the consequences of habits or impulses are deemed problematic, leaving someone indecisive about what action to perform. To decide what action to take in such a situation, a person needs intelligence. According to Dewey, human action is determined by what someone values. When a person is experiencing a problematic situation, where she is unsure what action to perform, she is thus unsure what she values. It is therefore that Dewey also refers to problem situations as indetermined situations (Dewey, 1942).

Intelligent conduct is concerned with transforming a problem situation into a determined situation and thus with figuring out what someone values and what actions belong with that. What we value is not based on some abstract idea, rather it is only in a situation that we figure out what is valuable to us (Fesmire, 2015). Value is thus situational. Because of this, value cannot be captured, it can only be experienced. Securing value therefore means having a valuable experience (Dewey, 1929). Rather than a state of mind, Dewey understands experiences as transactions with the environment (Dewey, 1910). With environment is Dewey not only referring to the physical milieu but it also includes social conditions (Fesmire, 2015, p. 250). Experiences are things we do, things we use, things we deal with; experiences are activities (Bernstein, 1971). It is through transactions with the environment that we gain knowledge of what is valuable to us in the specific situation and how we are able to realise the things we consider valuable. Intelligent conduct consists of two activities; inquiry – to determine the problem that is ran into and to identify potential solutions, and deliberation – to decide what solutions are likeable for the situation through which is figured out what someone values (Dewey, 1922b).

An indetermined situation is caused by an event that affects us, that causes a flux in intensive differences in our field of intensity (Williams, 2009). For instance, the event of the introduction of the idea of a digital twin caused an indeterminacy about safety standards and life expectancy of aircrafts. Experiences of indeterminate situations do not have to be as abrupt and total, but can concern only a small part of the situation. Moreover, many value judgements are often reused and the means to secure those value judgements are substituted. Consider for instance the digital twin of the airframe: inspection, prevention and maintenance was already part of the routine of using the aircraft in order

to make sure that the aircraft is save and functions well. The digital twin was proposed to take over the inspection and prevention tasks with the promise that the aircraft would become more save and have a longer life expectancy. The experience of an indetermined situation is the experience of being in an event itself – in a moment of change. Intelligent conduct is than the reciprocal determination of differential relations which determines the further actualisation (differenciation) of the virtual idea. Intelligent conduct is a means to stabilise an event by actualising it, however it also provides the opportunity to become sensible to differential elements, for intensification.

In digital twinning refers the event to the moment where the conditions that the data-link is supposed to register are still indetermined and before the information-link is used to perform an action. In this moment, the act of inquiry functions as a means for intensification and deliberation as a means to stabilise the situation by actualising the event along a sufficient reason. With digital twins for transformation should this moment be about intensification. For some digital twins is this moment very short which makes it necessary for sensory technology to help discover differential elements. Moreover, this moment is more and more being automated which pushes the individual out of the event and takes away its opportunity for intensification.

Inquiry and deliberation

Inquiry is concerned with articulating the problem that is ran into, formulating solutions to the problem, defining the means that will realise the solutions, and identifying the consequences of the formulated solutions and means (Dewey 1938; 1941; 1942). This is done through the construction and modification of propositions (scientific functions) through experimentation (Brown, 2012). Experimentation allows an individual to become sensible to differences. What Dewey draws extra attention to, same as Wilson (2017) did, is the fact that problems and solutions are simultaneously defined; when someone has the definition of a problem one also has the definition of the solution and vice versa (Dewey, 1929). Thus, it is not the case that problems have multiple solutions, but that problems can be defined in multiple ways. Problems and solutions are reciprocally determined as they both belong to the same sufficient reason.

The other activity of intelligent conduct is deliberation. Deliberation is a means to stabilise an event by distinguishing between desired and problematic actualisations of the virtual idea. This is done by judging the possible consequences of actions in terms of whether they are desirable or not (Fesmire, 2015). Because consequences are specific to a situation, we only find out what we value when we are faced with deciding on an action (Dewey, 1922a). Inquiry informs about the possible actions and their consequences, while deliberation directs the inquiry process. Actions can be understood as

means and consequences as ends. The value judgment that is being reflected upon must assess means and ends as a reciprocally determined package (Dewey, 1928).

The end that is selected as valuable by the value judgement is idealised. Deliberation is therefore understood as a method of idealisation.

> "There are three ways of idealizing the world. […] The third method represents the way of deliberate quest for security of the values that are enjoyed by grace in our happy moments." (Dewey, 1929, p. 302)[5]

It is by working towards an idealised end that value is secured in the form of a valuable experience (Dewey, 1929). Although it is called idealisation, deliberation is in fact a method of problematising undesirable states of affairs. It thus creates false problems because it does not go beyond the sufficient reason of the virtual idea, in fact, it actualises the virtual idea further. The actions that are performed to reach the desired end (and to have valuable experiences) are concerned with eliminating intensive differences that could result in undesired states of affairs. These intensive differences are identified in inquiry. Deliberation is thus a means to stabilise an event by problematising certain state of affairs. Inquiry and deliberation are not two stages which are completed separate from each other, rather they constantly inform each other in the process of making a situation determined (Anderson, 2023).

The relevance of acts in an event

In his ethics of the event, which will be further discussed in chapter 3, Deleuze brings to our attention that the act of choosing the desirable action (ethics) is impossible in the moment where in this action is required. An event – a moment of change – is something that happens to you, that you have to deal with, let alone something you can control. The individual is unable to fully apprehend the event in the moment that it is happening, and so, the individual can only be understood as a quasi-agent (Sholtz, 2016). Therefore, Deleuze proposes an ethics that concerns itself with events after they have happened, after it was actualised in a particular way, when the individual is fully conscious; a full agent. Deleuze's ethics of the event is a method for affirming the event in a way that provides us with "more favorable conditions for acting" (Bergson, 1946, p. 255) this allows us to get a grip on reality. The ethics of the event directs itself at the future and forgives regrettable actions of the past.

[5] The first and second methods of idealisation that Dewey discusses he disregards for the first, philosophy, is aimed at transcendence and the second, "intense emotional appreciation", is unregulatable (Dewey, 1929, p. 302).

For digital twins as a technology of transformation is the inquiry process of intelligent conduct more important than deliberation. The point is to get an as rich experience of the event as possible as this gives an individual more possibility to affirm an event into favourable conditions. Hence, the idealisation that an individual decides to pursue to get out of the indetermined situation is less important. However, an idealisation should of course not lead to the possibility of intensification being compromised.

Opportunities for intensification in digital twinning

For a digital twin to be referred to as a technology of transformation it should have opportunities for intensification in its practice. As mentioned intensification is the becoming sensible of an individual to new intensive differences and expand its field of intensity. Intensification can take place in the digital twinning process through engagement with the environment in the moment of an event through the act of inquiry. For an individual to be able to engage with an event, it needs to be somewhat stabilised by the construction of false problems through the act of deliberation. Below, I will discuss opportunities for intensification in acts of inquiry in practices of digital twinning.

Direct contact with real-world phenomena

Data-information links are often automated, with the result that direct contact with the real-world phenomenon becomes scarce after the construction of the digital twin. When data gathering and interventions are done manually, an individual remains part of the phenomenon of interest (of the milieu) and still get to be intensified by events that the digital twin is not concerned with. When these two activities are automated, the possibility for intensification decreases and with it the possibility to propose a new becoming for the phenomenon that the digital twin is concerned with. Deintensification narrows the possibility for transformation.

Engagement with stakeholders

Automation is limiting the possibility of intensification in digital twinning, nevertheless, besides direct contact with real-world phenomena are there also other methods for individuals to be intensified. For instance by engaging with a variety of stakeholders. A digital twin affirms a real-world phenomenon along a sufficient reason. Different stakeholders interested in the phenomenon, can affirm the becoming of the phenomenon along different sufficient reasons. By engaging with the sufficient reasons of other stakeholders an individual could intensify itself opening up possibility for transformation.

Trantas et al. (2023) discuss architectures for digital twins with multiple sufficient reasons (see figure 6). Although Trantas et al. (2023) provide a different understanding of these architectures, by use of the so far developed framework these architectures could be understood as (from top to bottom): (1) Politization of competing sufficient reasons; (2) Partial resonance between sufficient reasons; (3) Contraction of a duration by merging sufficient reasons. These architectures are used in cases such as: (1) Competing resources e.g. in water scarcity (Mehryar et al., 2019), waste management (Khalili et al., 2013), or livestock sustainability (Olde & de Boer, 2014); (2) Climate models (Trantas et al., 2023); (3) Biodiversity and ecosystem models (Trantas et al., 2023). In designing digital twins it is thus important to consider how the architecture is going to look like to maintain opportunities for intensification through facilitating engagement with other stakeholders. With these architectures should be must be watched out for singularisation as this makes digital twins technologies of control rather than technologies of transformation. Architectures that facilitate consensus such as the bottom one in figure 6 should therefore be avoided. These architectures should promote the multiplicity of the idea, such as the one at the top in figure 6, as this allows the individual to become sensible to new intensive differences.

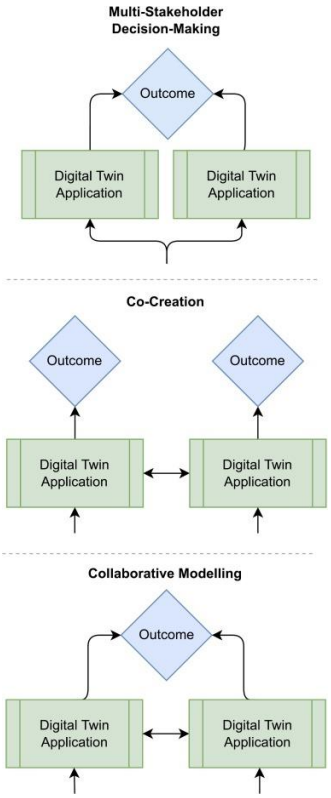

Figure 6: Architectures of digital twins with multiple sufficient reasons (Trantas et al., 2023, p. 8).

Exploration through simulations

Simulations could be used to explore possible actualisations of a virtual idea. Simulations are used in the deliberation process to gain an understanding of the behaviour of a phenomenon and the consequences of actions. Although simulations stay within the sufficient reason of the digital twins, as they rely on the digital model, they could be used to investigate the limits of a sufficient reason: through what differences a sufficient reason actualises and what not. In combination with direct engagement with the phenomenon and with stakeholders could intensification through simulations lead to a more distinct understanding of the idea that is being actualised and could novel intensive differences that fall outside the sufficient reason be explored. In chapter 3, is further elaborated on the role of simulations in the instrumentalisation of digital twins as technologies of transformation.

Conclusion

Because the legitimation mechanism that is currently used by digital twins, predictive and explanatory power, leads to instrumentalisation of digital twins as a technology of control, this chapter is concerned with developing a legitimation mechanism that could lead to the instrumentalisation of digital twins as a technology of transformation. Hence the chapter addresses the question: *What could be a legitimation mechanism for digital twins as technology of transformation?*

To address this question, the chapter develops a legitimation mechanism for digital twins as technology of transformation by use of the Bergsonian notions of true and false problems which Deleuze adopts in his work. From this analysis is concluded that intensification could be used as the legitimation mechanism for digital twins of transformation. Intensification refers to individuals becoming sensible to new intensive differences. For an individual to be intensified, it needs to be able to engage with the environment. To make this possible, needs a sufficient reason to be actualised first, so that the environment becomes less hostile through increased explainability and predictability.

The chapter gains a better understanding of the relationship between actualisation and intensification through John Dewey's theory of intelligent conduct that is used to navigate the experience of being in an event; of being in a moment of change. It is by being in a moment of change that individuals can intensify, though it is also when they can get harmed. In digital twinning refers the event to the moment where the conditions that the data-link is supposed to register are still indetermined and before the information-link is used to perform an action. In this moment, the act of inquiry functions as a means for intensification and deliberation as a means to stabilise the situation by actualising the event along a sufficient reason. With digital twins for transformation should the moment of being in the event be about intensification and thus not be compromised by actualisation. Deleuze's ethics of the event is able to justify this focus for the reason that a well-founded value judgement of an event can only be made when it is actualised, because only then is the individual a full-agent. As will be come more clear in chapter 3, the more intense the event for the individual the higher the possibility to affirm an event into favourable conditions.

Lastly, explores the chapter opportunities for intensification in digital twinning. Individuals can be intensified through direct engagement with the real-world phenomena in acts of inquiry and intervention. These acts of the data-information link are however more and more being automated, thereby reducing the possibility for intensification. Another possibility for intensification is through

engagement with stakeholders that are also concerned with the phenomena of interest. By engaging with the sufficient reasons of other stakeholders, an individual could intensify itself. The architecture of digital twins could facilitate intensification by allowing for engagement with the sufficient reasons of multiple stakeholders. It is however important that the architecture does not aim at consensus as this cancels the multiplicity of events and ends up in singularisation. The third opportunity for intensification through digital twinning is by engaging with simulations. Simulations could be used to investigate the limits of a sufficient reason. In combination with direct engagement with the phenomenon and with stakeholders could intensification through simulations lead to a more distinct understanding of the idea that is being actualised and could novel intensive differences that fall outside the sufficient reason be explored.

Chapter 3: **Digital twins as technology of transformation**

Introduction

This chapter combines the insights from the previous two chapter to explore how practices of digital twinning should be transformed to facilitate transformation with which it provides an answer to the question: *What modifications in the practice of digital twinning are required for digital twins to be technologies of transformation?* The chapter addresses this question by exploring how Deleuze's ethics of the event can become part of digital twinning by means of the activity of gleaning. Deleuze's ethics of the event stimulates transformation as it aims at developing new forms of being by transforming experience. By use of insights of chapter 2 are modifications to the practice of digital twinning proposed which mainly rely on the practices of data gathering, simulating and intervening. Finally, are these modifications explored in a case study that would benefit from the use of digital twins as a technology of transformation.

Deleuze's ethics of the event

Following Prášek (2024), the issue Deleuze addresses with his philosophy is the inability of humanity to be affected by the world. For Deleuze, to be affected by the world means to embrace the new possibilities of life that change (events) brings about. Accordingly, Deleuze thinks that humanity's crisis is its incapacity to change.

> "The modern fact is that we no longer believe in this world. We do not even believe in the events which happen to us, love, death, as if they only half concerned us [...] The link between man and the world is broken." (Deleuze, 2000, p. 171–172)

Consequently, the challenge that humanity should take up to and which also forms the basis for Deleuze's ethics is to "become worthy of the event" (Sholtz, 2016, p. 51). To become worthy of the event is to be affected by the changes – the events – that overcome you and to will those changes; to embrace the new possibilities that an event opens up and to consciously select a new form of life – a new form of being (Deleuze, 1990, p. 149–150). Deleuze's philosophy thus aims to transform our experience of reality.

Building on ideas of the Stoics and Nietzsche (Sholtz, 2016), Deleuze brings to our attention that the act of choosing the desirable action (ethics) is impossible in the moment where in this action is required. An event – a moment of change – is something that happens to you, that you have to deal

with, let alone something you can control. The individual is unable to fully apprehend the event in the moment that it is happening, and so, the individual can only be understood as a quasi-agent (Sholtz, 2016). Therefore, Deleuze proposes an ethics that concerns itself with events after they have happened, after it was actualised in a particular way, when the individual is fully conscious; a full agent. Deleuze's ethics of the event is a method for affirming the event in a way that provides us with "more favorable conditions for acting" (Bergson, 1946, p. 255) this allows us to get a grip on reality. The ethics of the event directs itself at the future and forgives regrettable actions of the past. It is concerned with affirming an event differently than how it was actualised, and thus it can be understood as an act of counter-actualisation. Below is explored how digital twins could facilitate transformation by use of the method of counter-actualisation.

Counter-actualisation

According to Deleuze, to affirm an event differently is to counter-actualise and event (Deleuze & Guattari, 1994). As discussed in chapter 1, actualisation is the process where ideas existing in the virtual gain spatio-temporal dimensions in the actual. Unlike current practices of digital twins which are focused on the actualisation of states of affairs, counter-actualisation is focussed on the events (ideas) that give rise to a state of affairs. Intensification of the individual – discussed in chapter 2 – forms the basis for counter-actualisation. When virtual ideas are actualised into states of affairs, the relation between the virtual idea and the state of affairs evaporates (Deleuze, 1994). As a result, access to possible alternative differentiations of the virtual idea has been lost. The act of intensification is concerned with overcoming this disconnect in order to open up the potentiality of events.

Overcoming the disconnect between the virtual idea and its spatio-temporal dynamisms makes it possible to have a say in the differen*t*iation of the idea. This way the differentiation of the idea turns into an agreement – an affirmation – rather than an acceptation.

> "To will the event one must also select it, actively affirming 'the embodiment and the actualization of the pure incorporeal event in states of affairs and in his or her own body and flesh' (Deleuze 1990: 146/172)." (Sholtz, 2016, p. 58)

Counter-actualisation is not just the countering of an actualisation but it is to actualise an idea differently. Counter-actualisation is thus the redistribution of singularities – the redistribution of events (Sholtz, 2016). By doing such thing, a virtual idea is intensified, meaning that a virtual idea expresses more of its intensive difference. Or put differently, it shows more of its multiplicity. Hence Shults (2014, p. 135) describes counter-actualisation as "a masterful intensification of intentional

engagement in the world". Counter-actualisation enables the individual to make a proper judgement about the nature of an event and allows the event to be lived differently through different intensive differences (Sholtz, 2016, p. 58). Counter-actualisation opens up the potential in ideas and is therefore a creative act.

After an individual is intensified by its milieu, the remaining procedure of counter-actualisation goes through three steps. The first step is to disassemble from extensions: the spatio-temporal dynamisms that conditioned the virtual idea. As Ott describes, "[o]rdinary life becomes physically, psychically and culturally attached to certain forms, so that the body is able to perform a narrow set of movements and the psyche behaves like a mental automaton, giving certain responses to certain stimuli" (Ott, 2019, p. 325). By disassembling these extensions, the individual reaches a point of zero intensity and creates space for new intensive differences. The second step is concerned with intensification of the idea by exploring new intensive differences – these are experienced as confused perceptions – that could hold a relation to the idea. This a stage of experimentation (Ott, 2019). The third step is to diversify the intensive differences of an idea. This means to affirm intensive differences that are different from the ones that are already actualised. This step results in the expansion of the multiplicity of the idea (Ott, 2019). Although we can distinguish these three steps, in reality these steps hold a close relation to each other and could happen simultaneously. Therefore, it makes more sense to treat them as aspects of the process of counter-actualisation.

For an example of counter-actualisation, consider the exemplary case of the aircraft that tries to prolong its lifespan by use of a digital twin. The event that has been unrolling for a while and that what the digital twin intended to prevent, namely, the ending of the lifespan of the aircraft, has gotten to a critical point. After the unrolling event of 'dead' of the aircraft, the aircraft is counter-actualised as playground equipment. The dead of the aircraft has been counter-actualised as becoming playground equipment. In this process, extensions where removed; e.g. flight schedules, and different intensive differences were intensified and affirmed. The dis-assemblage of extensions is not the material disassembling of extensions but it is the dis-assemblage of ideas that stabilise the conception that one tries to counter. It is the removal of false problems; distinctions that determine which state of affairs are desired and which not. After the counter-actualisation is the multiplicity of the virtual idea expanded. The aircrafts multiplicity for instance includes: the aircraft as a transportation device, as a means to make money, as a polluter, as producer of noise, and as playground equipment.

To be clear, counter-actualisation is not concerned with reviving the connection between a state of affairs and its original virtual idea. This would be a pointless search because the idea is a multiplicity

and there is no way to access the original intensive differences that determined the lines along which a state of affairs got to be differenciated. Rather, counter-actualisation is the search for a point where states of affairs interfere with each other outside the actualised sufficient reason (Plotnitsky, 2012). This point of interference could be understood as a singularity; an event; a moment of difference; a multiplicity, and is referred to as a concept (Deleuze & Guattari, 1994, p. 20). Counter-actualisation is thus concerned with reconceptualising events. Concepts always exist in a web of other concepts (Deleuze & Guattari, 1994). However, this web does not determine a concept. Concepts are consistent without having a reference point and are therefore both absolute and relative:

> "it is relative to its own components, to other concepts, to the plane on which it is defined, and to the problems it is supposed to resolve; but it is absolute through the condensation it carries out, the site it occupies on the plane, and the conditions it assigns to the problem." (Deleuze & Guattari, 1994, p. 21).

To counter-actualise, to reconceptualise, is not to merge different conceptions of an actualisation to a consensus, but to create a new conception of an actualisation (Bignall, 2014). Counter-actualisation is creative and should therefore result in a diversification rather than a singularisation. Counter-actualisation contributes to the multiplicity of an event and utilises the transformative potentials inherent to reality (Smith et al., 2023).

Gleaning

It remains difficult to understand how counter-actualisation could become part of the practice of digital twinning. By use of the concept gleaning, I will explain how each aspects of counter-actualisation – disassembly of extensions, intensification of the idea, diversification of sufficient reasons – could become part of the digital twinning practices.

Originally, gleaning was a practice of the poor that referred to "the act of gathering up and retrieving leftover crops from fields after the profitable harvest" (Carless, 2013, p. 160). In her documentary, Agnès Varda (2000) investigates modern interpretations of this practice as a way of dealing with waste and consumerism. Varda conceptualises gleaning as a practice of reviving what has been discarded (Carless, 2013, p. 157). The sorts of gleaning Varda shows in her documentary range from searching through garbage for a meal to making art from plastic waste.

Through the perspective from which Varda depicts gleaning – the problem of consumerism – her documentary emphasises the reviving aspect of the practice; to give that what society has discarded a second life. However, in order to glean, to counter-actualise, something first has to be discarded. When looking at discarding through the framework of Deleuze and Guattari, it could be formulated

as rejection of the event or the disassembly of extensions. The acts of gleaning Varda depicts show the reviving of things that are discarded by society (Cruickshank, 2007). Though, gleaning is not about discarding things (extensions), but it is about discarding ideas; the idea of food, the idea of art, the idea of waste, the idea of consumerism. And this is realised by discarding the extensions that actualised the event.

Revival refers to intensification and diversification of the idea. It is an act of opening up to new intensive differences by exploration, experimentation and eventually affirmation. According to Kruger (2024), experimentation is about putting things in relation, both socially as well as through physical engagement. It is about creating new possibilities by "sharing and living the memory of the other" (Kruger, 2024, p. 1108). An example of this is Varda's (2000) reconceptualisation of the filmmaker. By means of the documentary Varda reconceptualises the filmmaker as a gleaner; as someone that reconceptualises events – that affirms events differently (Cruickshank, 2007). Varda counter-actualised the becoming of the filmmaker by her social interactions with the gleaners which she captured on film, and the physical engagement with the camera, the shot footage and editing room.

It has to be noted that to affirm-an-event-differently is not simply to approach an event from a different perspective. Deleuze emphasises that through counter-actualisation – and actualisation as well – a complete reality gets to be created not just a part of it (Deleuze, 1988; Smith, 2007). That ideas are multiplicities means that they contain a multitude of realities, all different and coexisting (Deleuze, 1988). Counter-actualisation thus ends up with at transformation of experience. Gleaning could thus be understood as the embracement of confused perception, as giving in to undifferenciated intensive differences and exploring their potential. 'Praxis' of putting things in relation are essential with this as it allows the individual to "step outside [oneself] and intentionally open up the possibility of multiple passages and multiple crossings" (Mbembe, 2022, p. 109).

Simulating as a post-deliberation inquiry

As discussed in chapter 2, deliberation results in a value judgement – an idealisation – that leads to the actualisation of an event along the existing sufficient reason. From Deleuze's ethics of the event is learned that we can only form a well-founded judgment of an event in retrospect. Hence, counter-actualisation's are concerned with affirming events differently. In order to formulate a well-founded judgment about an event, an additional moment of inquiry is necessary which should become part of the practice of digital twinning. This post-deliberation inquiry should be understood as Varda's description of the filmmaker in the editing room, only than is the filmmaker a 'simulation-maker'.

Post-deliberation inquiry should be understood as a way to explore the limits of the sufficient reason that got to be actualised, it should be understood as gleaning.

In the post-deliberation inquiry should experiences of engagement with the real-world phenomena and stakeholders be used as input to explore alternative actualisations through simulations. It has to be noted that there should not be looked for a distinct simulation that shows a desired conceptualisation of an event. As this would not lead to the escape of the actualised sufficient reason, since it still forms the basis for the digital model that is used to perform the simulations. Rather, simulations should be used as a way to experiment with the through intensification collected differential elements and form the starting point for making these confused perceptions more clear by attempts at conceptualising these differences. With the ultimate goal to develop a new sufficient reason that transforms experience.

Part of the post-deliberation inquiry should also be to discard false problems. False problems are conceptions that serve the goal of directing the actualisation of an event to a desired state of affairs. These masquerade the differences that condition the event. The tool that Deleuze uses to dismantle false problems is Bergson's critique on negation (see footnote 2). For examples of the dismantling of false problems can be looked at the dissection of existing conceptions of digital twins in chapter 1 or the dismantling of the concept of biodiversity later in this chapter. It has to be noted that an attempt at counter-actualisation is no guarantee for the genesis of a true problem, though counter-actualisation allows the individual to get a grip on reality and "[place] us under more favorable conditions for acting" (Bergson, 1946, p. 255).

Gleaning in practice

In the remainder of this chapter I will further explore the attitude of affirmation by use of an exemplary case of a possible digital twinning project. I will use this case to demonstrate how false problems determine (stabilise) events and to point out opportunities for gleaning.

The case of Raine Island

Figure 7: Raine Island (State of Queensland, 2022).

The exemplary case that I will discuss is the Raine Island Recovery project (State of Queensland, 2021; 2022). This could be understood as a digital twinning project because systems of the island are provided with scientific explanations which are actively affirmed by use of data gathering methods, in other words there is a data-link between the real-world phenomenon and a digital model. Moreover, the state of the island that is captured in the digital model is assessed by comparing it to an ideal image and action is taken on that basis to influence the behaviours of the Island's system, thus there is also an information-link. The choice for the Raine Island project might not seem obvious as the project does not actively make use of contemporary digital twin technologies (yet), and there actually are various digital twinning projects[6] out there that do centre around these technologies. My choice for the Raine Island project is based on two reasons; Firstly, the Raine Island case is well documented and its practices are running for years which makes it possible to gain a good understanding of the project. Secondly, with the Raine Island case I would like to demonstrate that the practice of digital twinning does not have to be centred around advanced technologies. It is true that these technologies have a prominent position in digital twinning projects and that they do have an impact on the frequency with which data can be gathered and processed, but besides the

[6] As de Koning et al. (2023) discuss, there are many digital twinning projects being executed such as REDD+ and NVIDIA, and smaller projects like Geo-BON, NEON, eLTER, SAEON, TERN, GBIF, and LifeWatch. A lot of these projects, however are hard to gain information about or are still in an early stage of development in which the focus is on realising the sensing capability to provide real-life data. Moreover, for most projects are the directions that are planned to be taken after that unclear.

increase in pace, the digital twinning practice remains the same. Furthermore, it is likely that digital twin associated technologies do slip into the Raine Island project in the coming year since such technologies become more and more part of our scientific practices.

Located off the coast of Australia, Raine Island is of interest to various groups of people. These groups – the Australian national government, the Queensland state government and the Wuthathi People and Meriam Nation (Ugar, Mer, Erub) People – have started the Raine Island Recovery project (State of Queensland, 2022). This project intends "to re-establish and maintain Raine Island as a viable island" (State of Queensland, 2022). What it means for Raine Island to be a "viable island" can be derived from the four values that the island is considered to have and the stakeholders would like to preserve. These values help to map the current condition and trends of the island as well as to formulate desired conditions for the island to be in. The values have become significant to stakeholders because they are threatened by several factors as a result of climate change (State of Queensland, 2021). The four values are discussed below.

Raine Island as Country and culture

Raine Island forms a cultural landscape for Wuthathi People and Meriam Nation People. The cultures of these indigenous groups is strongly connected to the land. In fact, Country, as they call it, forms the basis for their cultures. The relationships and interactions that they have to Country forms the bases for their knowledge, language and practices. To preserve the cultures of the Wuthathi People and Meriam Nation People is thus to preserve Raine Island and vice versa. Access to a vital Raine Island is thus crucial for these groups as well as the ability to managing the Country (State of Queensland, 2021).

Raine Island as green turtle rookery

Raine Island forms the most important nesting site for the larges known green turtle population. This endangered species has been nesting on Raine Island for more than 1000 years. In a high season the amount of nesting turtles can go up to 60,000-80,000 (State of Queensland, 2022). Due to various changes in the Raine Island ecosystem the island has become a less vital nesting site. As the green turtle population has been declining for years, preserving and revitalising the Raine Island ecosystem can have a positive effect on the green turtle population (State of Queensland, 2022).

Figure 8: Turtles are hindered by rocks to reach the beach where they can make their nest (State of Queensland, 2022).

Raine Island as seabird nesting habitat

Raine Island is also the most diverse seabird rookery in the Great Barrier Reef (GBR) region. Therefore, keeping Raine Island available for all these different bird types is important for maintaining the seabird population of the GBR (State of Queensland, 2021; 2022).

Raine Island as maritime and mining heritage

The stone beacon in the middle of the island is one of the oldest colonial stone buildings build by convicts in the state of Queensland. The beacon, which was built in 1844, has important historical as well as aesthetical value for various groups such as the state of Australia and the state of Queensland but also for the Wuthathi People and Meriam Nation People as the beacon marks the post-contact era in their culture (State of Queensland, 2021; 2022).


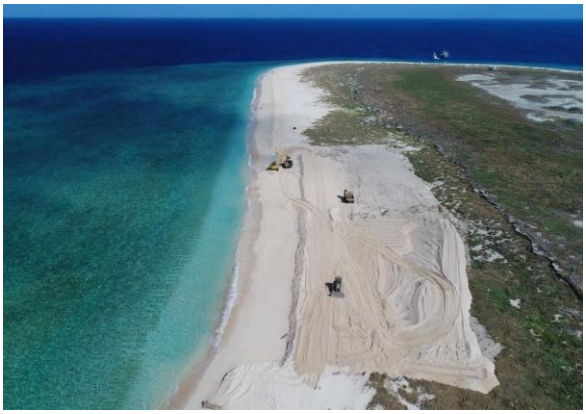

Figure 9: Fencing to prevent turtles from falling of the cliffs and re-profiling of beaches (State of Queensland, 2022).

Idealisation and actions

The four values could be understood as four conceptions of the island that have existed throughout time and across different stakeholder groups. The project tries to actualise these conceptualisations simultaneously so that the island can be a place for animals, a cultural landscape for Wuthathi People and Meriam Nation People, a marine beacon and a research site. Various practices are performed to actualise all four conceptions of Raine Island. For example, the beaches of Raine Island are re-profiled every 5 years to make sure that there is enough nesting space for the turtles and the island has 1100 meter of fencing placed around its cliffs in order to stop turtles from falling off. Moreover, only scientists and traditional owners are allowed to visit the island to perform measurements, counts and help animals in trouble. Next to that are the conditions of the island and wildlife populations constantly remotely monitored and is language of traditional owners used to refer to animals and locations.

The measures that are taken are supposed to help regulate the trajectory of becoming of Raine Island. They are supposed to bridge the gap between the constructed ideal of what Raine Island is desired to be and the state of affairs it is actualising into due to the unrolling event of climate change. The practices are on the one hand concerned with inquiry, which leads to the construction of scientific propositions and further actualises the event. On the other hand, are practices concerned with interventions to avoid problematised state of affairs from actualising. These practices are based on a deliberation process that is concerned with "limiting the negative effects of climate change" (Harry & Morad, 2013).

Reflection on the case

The ideal of what Raine Island could be and the practices that are performed to realise that ideal are heavily influenced by the hegemonic conception of climate change. The Raine Island Recovery

Project could thus be understood as part of the unfolding idea of climate change. This event forms the motivation for the project, brought the four values together and has been directing the inquiry and deliberation processes on Raine Island (Hopley, 2008). Of course, the four becomings of Raine Island are interacting[7] with each other for a long time already, but it is because the common threat of climate change that they have become allies. Looking at early documents of the Raine Island Recovery Project, the actions that were being performed were less distinctly motived by the threat of climate change. They were motivated by early environmentalist motivations such as internal value of species rather than conservation of ecosystems (Hopley, 2008).

Counter-actualising the becoming of Raine Island

As the Raine Island Recovery Project further positions itself in the event of climate change – which refers to significant changes in the climate whose causes can be traced back to human activity (Vlassopoulos, 2012; Harry & Morad, 2013) – it also becomes more conditioned by the web of concepts in which the notion of climate change is embedded, such as sustainability, biodiversity, mitigation and adaptation. Moreover, the event is also becoming increasingly stable – contracted – by false problematisation. In order to counter-actualise the becoming of Raine Island, it needs to be isolated from the conceptual framework and false problems by which it is conditions. As an example, I will discuss disassemble the false problem biodiversity.

Biodiversity as a false problem

If we apply Deleuze's reasoning about true and false problems[8] to the concept of biodiversity, it can be explained as a false problem. This is because it is not an intrinsically productive concept that stands on its own, but its existence depends on external conditions (Schrickel, 2020). In fact, biodiversity is the negation of the concept of monoculture. Monoculture refers to a by humans constructed ecosystem that only houses a single species. This development – which fits into a trend of marketisation and could therefore be placed in the unfolding event of capitalism – is seen as a major cause of instability and degradation of ecosystems (European Commission: Directorate-General for Environment, 2021). Because of this, this actualisation – ecosystems that only house a single species – is being problematised. The problematisation of monocultures is thus a problematisation of a state of affairs. Rather than problematising the underlying sufficient reason that led to its actualisation – capitalism – one problematised the state of affairs and decided to make a distinction between desirable and undesirable state of affairs. The concept biodiversity is supposed to indicate a desirable state of affairs. That biodiversity is a negation of monoculture – an opposition

[7] Deleuze and Guattari discuss the interactions between events in their book *A Thousand Plateaus* (1987).
[8] Deleuze refers to this as Bergson's method of intuition (Deleuze, 1988).

– is also reflected in the terminology: mono = single, culture = human made; bio = nature made, diversity = plural. To make sure that biodiverse ecosystems are actualised instead of monoculture ecosystems, intensive differences (e.g. pesticides and nitrogen deposition) are being regulated (European Commission: Directorate-General for Environment, 2021). To be clear, that biodiversity could be considered a false problem does not mean that there could not be a positive conception (a true problem) of the added value of a diverse ecosystem. It is only that this should come forth out of a counter-actualisation of the underlying event that was actualised.

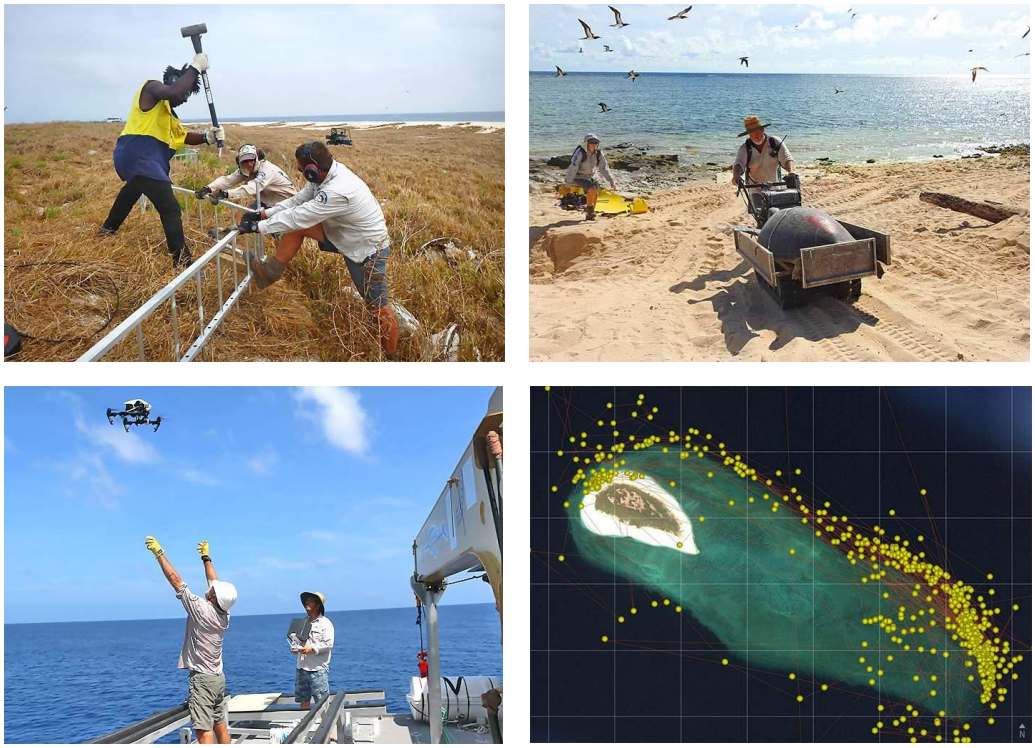

Figure 10: Intervention and data gathering activities on Raine Island (State of Queensland, 2022).

Opportunities for gleaning

Gleaning is concerned with intensification and diversification of the idea. It is an act of opening up to new intensive differences by exploration, experimentation and eventually affirmation. Besides pragmatic (political/ethical) aims, the aim of gleaning is to affirm the event differently and contribute to the multiplicity of the idea. Above I have disassembled an extension – false problem – that determines the becoming of Raine Island. For counter-actualisation it is necessary that after discardation space is made for revival, hence in what follows I will discuss some opportunities for intensification of the idea that could lead to gleaning. Intensification is about becoming sensible to intensive differences that fall outside the sufficient reason of the event that is unfolding. These intensive differences are experienced as confused perception as they do not belong to a differentiated (distinct) idea. Chapter 2 identified three possibilities for intensification in digital

twinning: direct contact with real-world phenomena, engagement with stakeholders, and exploration through simulations.

As figure 10 demonstrates, most of the data gathering and intervention activities in the Raine Island project are performed manually. This provides direct contact with the phenomena of interest which gives opportunities for intensification. Although activities that are performed are directed by a management statement that tries to satisfy the desires of each stakeholder group, how the activities are executed is still up to the people that perform them. This allows for iterative processes and practices of putting things in relation to each other that could be valuable for intensification and diversification. Consider for example the activity of moving turtles. This could be a well-planned job where everything runs smoothly, however there are always unexpected events that can occur that one has to deal with, where one has to improvise. For instance, when the turtle carrier breaks down. This provides opportunities to become sensible to new intensive differences. When data-information links are automated these possibilities become much less.

Another opportunity for intensification is through stakeholder engagement. The Raine Island project is bringing the conceptions of the island in conversation with each other by having social interactions between the different stakeholder groups. This could for instance be about conflicting actions that are necessary to actualise the desired ideal. For example, initiatives to reprofile the beaches of Raine Island to restore the nesting habitat of turtles potentially negatively impacts the nesting habitat of seabirds (State of Queensland, 2021, p.22). Moreover, stakeholders are forced to get in contact with intensive differences of other groups as only the traditional owners' language is used to refer to locations, plants and animals and the data gathering methods are mainly stemming from contemporary scientific practices. Following Deleuze, it is important that consensus is productive in the sense that it does not reduce the multiplicity of an idea but adds to it. The project also draws attention to who are the people that come in contact with the phenomenon and what there relation is to the phenomenon. In the project are only scientists and traditional owners allowed to set foot on the island and perform activities of data gathering an intervening. These two groups have a strong interest in the island and are connected to the project for a long time. Moreover, these groups have a strong say in the becoming of the island. It is important to take these factors into account in the engagement with other stakeholders.

Conclusion

The chapter addresses the question: *What modifications in the practice of digital twinning are required for digital twins to be technologies of transformation?* The chapter proposes the modification of introducing a post-deliberation inquiry process that is concerned with counter-actualising the event that currently actualises the phenomenon of interest in order to affirm the event differently. The different affirmation of the event is a transformation of the sufficient reason that determined that actualisation of the event. Counter-actualisation thus leads to the transformation of experience. The post-deliberation inquiry of digital twinning should be understood as a method of gleaning by simulations. Intensification by experiences of engagement with the real-world phenomena and stakeholders are used as input to explore alternative actualisations through simulations. Simulations should be used as a way to experiment with the through intensification collected differential elements and form the starting point for making these confused perceptions more clear by attempts at conceptualising these differences. With the ultimate goal to develop a new sufficient reason that transforms experience.

Conclusion

The thesis promises to be a solution to the problem that the way digital twins are currently being used, that is as technologies of control, creates experiences of oppression. The solution that the thesis proposes to this problem is to substitute the understanding of digital twins that leads to them being used as technology of control with a different understanding. The thesis argues that a different conceptual framework for digital twins could facilitate a different instrumentalisation of digital twins. The alternative use case that the thesis proposes is to use digital twins as instruments of transformation. This use case gains relevance due to the fact that contemporary views on tackling societal problems belief that these problems require a transformation of the systems that led up to these problems and because of that also a transformation in the way that is thought about these problems (Campbell et al., 2019; Schrickel, 2020). Therefore, the thesis addresses the question: *What could be a conceptual framework for digital twins that would enable them to be used as a technology of transformation and what adjustments are needed in the practices of digital twins to achieve such an instrumentalisation?*

Answering the research question

The difficulty in answering the research question is that there is no empirical case from which a conceptual framework could be derived, since there is no case of digital twins as instruments of transformation. A specific conceptual framework could help the development of practices of digital twinning for transformation and meet the need that is expressed. However, as mentioned, there is no empirical case from where such a framework could be derived. Thus, we end up in a paradox that limits us in developing a new conceptual framework for digital twins, even though there is a need for it. Gilles Deleuze's transcendental empiricism is a method to break open this paradox (Smith, 2015) and is therefore used to formulate an answer to the research question. For an explanation of transcendental empiricism can be looked at the introduction of the thesis. The research question was answered by use of three sub-questions that each occupy a chapter of thesis.

Chapter 1 addresses the question: *What could be a conceptual framework for digital twins that would enable them to be used as a technology of transformation?* The chapter develops a conceptual framework for digital twins by use of an empirical account of digital twins and the metaphysics of Gilles Deleuze. The chapter concludes that digital twins that lead to experiences of control can be understood as a method for regulating the course of becoming of a phenomenon. Digital twins affirm the becoming of a phenomenon along a sufficient reason by use of their data-link and try to regulate the becoming by regulating the intensive differences with which a phenomenon comes into contact

by use of the information-link. The mechanism that is used to legitimise digital twins, that is accuracy: predictive and explanatory power, leads to situations of oppression and control because it leads to the further actualisation of hegemonic sufficient reasons. By replacing the legitimation mechanism opens up the possibility to use digital twins differently, to use digital twins as a technology of transformation.

Chapter 2 addresses the question: *What could be a legitimation mechanism for digital twins as technology of transformation?* The chapter concludes that intensification could be used as the legitimation mechanism for digital twins of transformation. Intensification refers to individuals becoming sensible to new intensive differences. For an individual to be intensified, it needs to be able to engage with the environment. To make this possible, needs a sufficient reason to be actualised first, so that the environment becomes less hostile through increased explainability and predictability. It is by being in a moment of change that individuals can intensify, though it is also when they can get harmed. In digital twinning refers the event to the moment where the conditions that the data-link is supposed to register are still indetermined and before the information-link is used to perform an action. In this moment, the act of inquiry functions as a means for intensification and deliberation as a means to stabilise the situation by actualising the event along a sufficient reason. With digital twins for transformation should the moment of being in the event be about intensification and thus not be compromised by actualisation. Deleuze's ethics of the event is able to justify this focus for the reason that a well-founded value judgement of an event can only be made when it is actualised, because only then is the individual a full-agent. Lastly, in digital twinning are three opportunities for intensification: through direct engagement with the environment, by engagement with the sufficient reasons of other stakeholders, and by engagement with simulations.

Chapter 3 addresses the question: *What modifications in the practice of digital twinning are required for digital twins to be technologies of transformation?* The chapter proposes the modification of introducing a post-deliberation inquiry process that is concerned with counter-actualising the event that currently actualises the phenomenon of interest in order to affirm the event differently. The different affirmation of the event is a transformation of the sufficient reason that determined that actualisation of the event. Counter-actualisation thus leads to the transformation of experience. The post-deliberation inquiry of digital twinning should be understood as a method of gleaning by simulations. Intensification by experiences of engagement with the real-world phenomena and stakeholders are used as input to explore alternative actualisations through simulations. Simulations should be used as a way to experiment with the through intensification collected differential elements and form the starting point for making these confused perceptions more clear by attempts

at conceptualising these differences. With the ultimate goal to develop a new sufficient reason that transforms experience.

Discussion: Assumptions and limitations

There are several remarks and limitations to the presented argument. The first I would like to point out is that the research does not explicitly take into account the influence of capital on the practice of digital twinning, while the deployment of digital twins often holds monetary motivations that shape pragmatic aims. Deleuze and Guattari's work in *Anti-Oedipus: Capitalism and Schizophrenia* (1972) goes more into the role of capital on experience and could therefore be used to further develop the proposed account. Another remark is that the inquiry is little concerned with entities other than human although many digital twin applications are involved with non-human entities such as material objects, plants and animals. Accounts that take into account nonhumans recognise that humans are part of a larger system and try to displace the human from the centre of analysis (Roffe & Stark, 2015). The inclusion of Deleuze's concept of multiplicity makes that the analysis recognises the positionality of our experience of reality[9]. The account offered, however, still places the human individual at the centre of the analysis, hence future research could focus on developing a decentralised understanding of digital twins. This would allow for the development of a wider ethics of digital twinning.

Lastly, the main limitation of this thesis is that it is based on testimonies of digital twins and of the way they are used. Although these testimonies provide detailed accounts of digital twins, without engaging directly with a digital twin or a digital twin expert it is hard to check the quality of the testimonies that were used. Moreover, as the thesis develops a practice of digital twinning for transformation, it would have been good to gather feedback about the suggested practices from people that have experience with engaging with digital twins. However, although this would have been beneficial for the quality and legitimacy of the account, this should be understood as the next step in the development of digital twins as technology of transformation. The presented account should be understood as a starting point for the development of digital twins as technology of transformation and the discussion about it.

[9] Deleuze stresses that we should not understand our observations as relative, but rather reality itself as inherently relative (Deleuze & Guattari, 1994).

Applications of knowledge & future research

Below I outline some possibilities for applications of the insights from this thesis beyond digital twinning and for future research.

The Anthropocene

The concept Anthropocene refers to the period of time currently lived in, where the human is having such a substantial influence on the earth's systems that it has become a "geological force" (Chakrabarty, 2012, p. 2). Put differently, the concept of the Anthropocene refers to the event of the world becoming affected by humanity. As discussed, Deleuze's ethics of the event is concerned with making humanity be affected by the world. In Deleuze's ethics is the world the source of change for humanity, in the Anthropocene functions humanity as a source of change for the world. And where change in humanity in the philosophy of Deleuze is considered something good, change in the world in the Anthropocene is considered something bad. In short, the event of the Anthropocene asks us to think about our methods for shaping and creating experience and consider the non-human actor. The event of that Anthropocene requires as to rethink how digital twins create our experiences.

A process philosophy of technology

The works of both Deleuze and Dewey are considered process philosophies as both authors emphasise the dynamic and creative nature of reality and hold a non-foundational understanding of existence (Seibt, 2024). In the philosophy of technology it has been a popular idea to construct a process philosophy of technology and so do justice to the temporal dimension of reality and technology. This thesis could be seen as an attempt of providing a process philosophical account on a technology and could be used as a starting point for future inquiries.

Digital twinning vs market creation: two mechanisms for world making

Digital twinning could be seen as an alternative regulation mechanism to market creation. In green policy, market creation is used as a mechanism to for regulating the becoming of phenomenon, for instance in the case of carbon emissions. Future research could go into comparing these two approaches for regulating phenomena.

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