Philosophy of Big Data

Expanding the Human-Data Relation with Big Data Science Services

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***Abstract*—Big data is growing as an area of information technology, service, and science, and so too is the need for its intellectual understanding and interpretation from a theoretical, philosophical, and societal perspective. The Philosophy of Big Data is the branch of philosophy concerned with the foundations, methods, and implications of big data; the definitions, meaning, conceptualization, knowledge possibilities, truth standards, and practices in situations involving very-large data sets that are big in volume, velocity, variety, veracity, and variability. The Philosophy of Big Data is evolving into a discipline at two levels, one internal to the field as a generalized articulation of the concepts, theory, and systems that comprise the overall conduct of big data science. The other is external to the field; as a consideration of the impact of big data science more broadly on individuals, society, and the world. Methods, tools, and concepts are evaluated at both the level of industry practice theory and social impact. Three aspects are considered: what might constitute a Philosophy of Big Data, how the disciplines of the Philosophy of Information and the Philosophy of Big Data are developing, and an example of the Philosophy of Big Data in application in the data-intensive science field of Synthetic Biology. Overall a Philosophy of Big Data might helpful in conceptualizing and realizing big data science as a service practice, and also in transitioning to data-rich futures with human and data entities more productively co-existing in mutual growth and collaboration.**

Keywords—big data; philosophy; information; scientific method; research; methodology; human-data relations

"*The Philosophy of Information is a completely new development with a capacity to revolutionize philosophy and human interactions with science, technology, data, and reality*"
- Luciano Floridi, Philosophy of Information, Oxford [1].

I. Introduction

One of the strongest new presences in contemporary life is big data, very-large data sets that may be big in volume, velocity, variety, veracity, and variability. Data volumes and activity are similarly 'big' in four areas: scientific, governmental, corporate, and personal data. Gartner's hype cycle for emerging technologies analysis presents big data as crossing from the 'peak of inflated expectation' into the 'trough of disillusionment' in 2014 [2]. Per this reference, the suggestion would be that big data has matured; it has passed out of hype and arrived as a field, and should proceed forward in defining many classes of services with different value propositions for different audiences. One implication of big data is that humans are having a wholly different concept and new way of relating to data. Where formerly everything was signal, now 99% is noise, which can possibly lead to overwhelm, especially if there is a failure to adequately filter the information. Instead of every-item-is-salient, the new human modes of interacting with data are those of exception, variability, probability, patterns, and prediction, which are not necessarily natural modes for humans. There are new kinds of information available for the first time such as very-deep micro-detail, longitudinal baseline measures, normal deviation patterns, contingency adjustments, anomaly, and emergence. Humans can conceive of the relation to data as one of reality multiplicity given the different attunements of data analysis paradigms, for example those structured around time, frequency, episode, and cycle. There are new kinds of epistemic models that at minimum supplement and extend the traditional scientific method, such as deep learning, hierarchical representation, neural networks, and information visualization.

Individuals can feel powerless in the relation to data. This is because the human-data relation is asymmetric; there seems to be an asymmetry of control with data having the upper hand. There is a sense of wary uncanniness and helplessness that somehow "*data can see and manipulate us without our being able to see and manipulate them*." Drones are one such example of the modern powerlessness of the individual in the face of data and technology in that they can see without being seen, and touch without being touchable [3]. In the human-data relation, there is a thin line between measurement and manipulation which is difficult to discern because we do not have a previous reference point for appropriate ways to interact with large amounts of data. It is our inclination is accept the authority of a recommendation ('*Siri must know me better than I know myself*') without being able to adequately evaluate whether following a recommendation is an expansion or diminution of our freedom, awareness, self-expression, and humanity [4].

I argue that the cornerstone issue is an incomplete subjectivation by both sides; neither party, data nor humans, has a complete and full understanding (humans) or representational model (data) of the other. Neither side has accorded full alterity, or otherness, to the other, and poor relations are the result. A full sense of the other party is lacking in their interrelation. Data creates a false metonymy (whole) in trying to subjectivate a complete individual from a partial data stream. Data models humans too narrowly, exclusively as social identity profiles or economic purchasing agents, not as full persons. Humans are unable to see and conceive of the intangible entity that is 'big data,' understand how to interact with it, and how to evaluate the meaning of these interactions. Thus one aim in developing the Philosophy of Big Data as a fully-fledged field of inquiry is both to investigate an immediate slate of philosophical issues relating to the foundations, methods, and implications of big data science, and also to tackle a more profound tier of concerns for the purpose of improving and extending the possibilities for human-data relations. This is important for facilitating smooth transitions to a future that could include both humans and data entities existing productively in mutual collaboration.

A. General Definitions

Many terms and their evolving definitions are contemplated and discussed throughout the paper and therefore a baseline lexicon of definitions is supplied here as a reference and starting point. **Data** is facts and statistics collected together for reference or analysis. **Information** is facts provided or learned about something or someone. Both may be used as a basis for reasoning or calculation. While there used to be more of a distinction between data as underlying facts and statistics, and information as knowledge gleaned from these facts and statistics; the definitions have now become quite close and may be synonymous in use. **Big data** is high-volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making [5]. Big data may be assessed per 5 "V" parameters: volume, velocity, variety, veracity, and variability. **Data science** is the extraction of knowledge from data [6]. Data science includes big data, and is conceived as a broader discipline that employs techniques and theories from mathematics, statistics, computing, and information technology, for example machine learning, to uncover patterns in data from which predictive models can be developed. **Data-intensive Science** (also eScience or computational science) is computationally-intensive science involving very-large data sets that may require data science computing techniques for comprehensive high-dimensional modeling, observation, and experimentation, and may be carried out in distributed network environments.

Philosophy is the study of the fundamental nature of knowledge, truth, reality, and existence. The field's efforts can be broadly organized into three general categories: ontology, epistemology, and ethics. Ontology deals with existence; what is big data, how does it arise, how does it operate in the world; definitions and classifications. Epistemology deals with knowledge; how is big data helping us know new things about the world, how true are these findings, what knowledge is required to engage in big data science. Ethics deals with how big data science is conducted, how certain kinds of findings get valorized and why; aesthetics is also part of this category (what gets seen and valued as beautiful or aesthetically pleasing). A philosophy of anything should provide a concise definition of what it is and articulate its purpose and dimensions.

The **Philosophy of Science** is a branch of philosophy concerned with the foundations, methods, and implications of science. The central questions concern what counts as science, the reliability of scientific theories, and the purpose of science. The various philosophies of data/information, big data, data science, and data-intensive science can be understood in this standard framework of **foundations, methods, and implications**. The **Philosophy of Data/Information** is a branch of philosophy concerned with the foundations, methods, and implications of data and information; the existence, definition, conceptualization, methods, knowledge possibilities, truth standards, and practices of working with data and information. The **Philosophy of Big Data** is a branch of philosophy concerned with the foundations, methods, and implications of big data; the definitions, meaning, conceptualization, knowledge possibilities, truth standards, and practices in situations involving high-volume, high-velocity, high-variety information and very-large data sets. The **Philosophy of Data Science** is a branch of philosophy concerned with the foundations, methods, and implications of data science, science that extracts knowledge from data using techniques and theories from mathematics, statistics, computing, and information technology. The **Philosophy of Data-Intensive Science** is a branch of philosophy concerned with the foundations, methods, and implications of data-intensive science; the definitions, meaning, knowledge production possibilities, conceptualizations of science and discovery, definitions of knowledge, proof standards, and practices in situations of computationally-intensive science involving large-scale, high-dimensional modeling, observation, and experimentation in network environments.

II. WHAT IS INFORMATION?

A. Quantitative and Qualitative Definitions of Information

While the basic dictionary definition of information is facts provided or learned about something or someone that may be used as a basis for reasoning or calculation, a deeper consideration of the term in practice quickly leads to other complexities. The exact meaning of information may vary considerably in its wide range of use in different formal and informal contexts. One fundamental structuring is that there are both quantitative and qualitative definitions of information. Table I presents a sample list of these formulations [7].

TABLE I. FORMULATIONS OF THE CONCEPT OF INFORMATION

Information Theory	Underlying Mechanism	Class of Theory
Shannon Information	Probability	Quantitative
Fisher Information	Probability	Quantitative
Kolmogorov Complexity	Computation	Quantitative
Quantum Information	Quantum Mechanics	Quantitative
Semantic Information	Truth, Accuracy	Qualitative
Information as a State of an Agent	True Beliefs (propositions that need not be true, but are believed to be true)	Qualitative

The historical notion is a quantitative one, where the concept of information can be understood as an effort to make the extensive properties of human knowledge measurable. The scientific method has been employed in attempts to quantify, measure, and harness the concept of information into a measurable quantity. This could also be called an effort to scientify information. Towards this end, in the second half of the 20th century, various proposals for information quantification and the formalization of the concept of information.

Most generally a contemporary quantitative formulation of information could be any amount of data, code, or text that is stored, sent, received, or manipulated in any medium [4]. A frequent reference point when considering the definition of information is Shannon information. Named for Claude Shannon at Bell Labs who proposed the idea in 1948, Shannon information is a quantitative and technical definition of information. It is the quantified measure of the information content in a message, and the probability of receiving this message. This measure varies by context (such as people named Li in Germany versus people named Li in China). The quantitative measure is then used operationally to translate, transmit, and reassemble messages between contexts. For example, different amount of bits will be required to specify the same message, Li, in the different contexts of Germany and China. Thus, Shannon information is "*a quantified measure of the information content and probability of a certain message in a certain context*" [8]. The formulation of Shannon information would be able to answer questions like the probability of someone being named Claude in a certain group of people, and how many bits are required to encode this information in specific contexts. Shannon's theories have been widely applied in modern communications networks to ensure the fidelitous transmittal of messages over distance. While Shannon information is perhaps the most prominent quantitative definition of information, there are also others such as Fisher information, Kolmogorov complexity, and quantum information. Without going into specific details, some common parameters engaged in these equations are quantitative formulations of content, entropy, probability, and updating.

There are also qualitative formulations of information, with two presented in Table I. One theory is semantic information as truth, which is the idea of focusing on the properties of the data as an indication of quality. These properties could include the data being well-formed, meaningful, and truthful. Another qualitative formulation is information as a state of an agent. Truthful data is not a requirement in this definition, but rather the focus is on the subjective experience of information, whether an agent experiences an information proposition to be true. These are just two examples, and there is ample room to extend the qualitative formulation of information, for example in the concept of Bergsonian information, the internal sense of the experience of information itself [9].

B. *The Contemporary Study of Information*

The situation of the philosophical consideration of information is similar to that of energy. The term is used commonly in daily speech to refer to a number of contexts. In addition, more formally, there are various mathematical formulations of energy such as kinetic, potential, electrical, chemical, and nuclear. There are also qualitative senses of energy. In fact many philosophies attempt to explore and articulate both the quantitative and qualitative sides of different phenomena as a central theme. These include the philosophies of time, space, self (personal identity, the individual, consciousness), cognition, cognitive enhancement, and data, big data, and human-data relations.

Table II provides a short list of topics and references that are fields of concern within the study of information [7]. Several philosophers consider the field as a whole, and the three main philosophical categories of ontology (existence), epistemology (knowledge, logic, and reasoning), and ethics and aesthetics. Others consider the history of the study of information, and a recent topic of interest, the possibility of unifying different theories of information. From a philosophy of information perspective, the key point is to be aware that there are many different kinds of definitions of information and to check and articulate specifics as required in any situation.

TABLE II. FIELDS OF CONCERN WITHIN INFORMATION

Area	Notable References
General	Adriaans and van Benthem 2008; Lenski 2010; Floridi 2002, 2011
Ontology	Zuse 1969; Wheeler 1990; Schmidhuber 1997b; Wolfram 2002; Hutter 2010
Logic	Dretske 1981; van Benthem en van Rooij 2003; van Benthem 2006
Ethics	Floridi 1999, Booch 2014
Aesthetics	Schmidhuber 1997; Adriaans 2008
History	Seiffert 1968; Schnelle 1976; Capurro 1978, 2009; Capurro and Hjørland 2003
Unifications	PRO: Cover and Thomas 2006; Grünwald and Vitányi 2008; Bais and Farmer 2008; CON Adriaans and van Benthem 2008a

III. WHAT IS THE PHILOSOPHY OF INFORMATION?

A. *Overview*

The next phase of the paper explores the current progress of the Philosophy of Information as it is developing as a field. The basic definition is that the Philosophy of Data or Information is the study of the foundations, methods, and implications of data and information. As with other philosophies of science, there are two main tiers of concern in the Philosophy of Information, at different levels of abstraction removed from the actual underlying practice. The first is internal to the field; an articulation of the concepts, theory, and systems that emerge to describe the overall conduct of science within the field. The second is external to the field; the impact of the field more broadly on individuals, society, and the world. The internal develops first as standard practice activities coalesce into a higher level of generalization. The external then develops second as the field becomes a full-fledged entity, and its placement in society can be evaluated, along with influence on social, legal, and ethical issues. The three categories of philosophical concern (ontology, epistemology, and ethics) can apply equally to the practice theory level and the societal impact level of the Philosophy of Information. The two tiers of the nascent Philosophy of Information are discussed and then their concretization in methods, tools, and concepts.

1) First Level of Abstraction: Internal Practice Theory

The internal practice theory level sees the philosophy of information as the technical discipline and conceptual knowledge arising from practitioners in the field. This level might be characterized as 'big data theory.' This is the theories, concepts, and sense-making models that are used primarily within the practice. It is the internal process of characterizing what has been emerging from the practice such as common theories, structures, practices, assumptions, and commonalities. These are overall theories that emerge to describe the practice. Epistemic questions can be asked about the production of knowledge, such as what counts as knowledge, how do we know, what is the proof standard, and how is this related to empirical experimentation. Ethical and aesthetic questions can be asked about the production of information, how and which data elements get noticed, included or omitted, and valorized, and how they are used in practice. A concrete example of the internal practice theory level is a new concept developing from practice that becomes a key idea known and used by all, such as a distributed file system, a concept that has become central in the practice of big data science with Hadoop system architectures.

2) Second Level of Abstraction: Societal Impact

The external societal impact level sees the philosophy of information as the assessment of the field's impact on society. It is one or more levels of abstraction removed from the actual practice. Being external to the practice allows the ability to conceive of the field as a whole and evaluate the placement and meaning of the field in the world more generally. Philosophical questions are considered about the ontological definition of the field, what its dimensions, boundaries, and growth trajectories are, what it might mean for humans, and how the practice might change how we think about ourselves and the world. Further, the social influence; what is the impact of this industry, practice, and findings on society more broadly. A concrete example of the external societal impact level is the concept of the biocitizen. This is a shift in how man sees himself as a result of big data science, how having access to one's own data like personal genome and microbiome files has shifted man's sensibility about what it is to be human, and enabled new responsibilities and ways of acting the world. For example, having your own genomic data means being able to look up your status for new situations as research is published, such has whether your brain is wired for neuroplasticity [10] or Alzheimer disease [11], and whether you have the anger, happiness, and compassion genes [12-14]. Interacting with personalized big data is fundamentally changing man's view of what it is to be human in the world, and also what the world and its possibilities are.

The basic definition of the Philosophy of Information (concerned with the foundations, methods, and implications of information), is in accord with these two levels. Foundations and methods are at the practice theory level, and implications are at the societal impact level. Both tiers are evolving as disciplines, and a more detailed look at their progress now ensues through an analysis of three of the most important developmental areas: method, tools, and concepts.

B. Method

One important topic for investigation in the Philosophy of Information is method. Typical of this class of philosophical issues is definition, terminology, approaches, classification, information organization, question-asking, proof and evidence standards, adequation, and *explanandum-explanans* linkage. In *explanandum-explanans* linkage, philosophers look at the degree and type of connection between that which needs to be explained (*explanandum*) and that which contains the explanation (*explanans*). Adequation is a kind of analysis in *explanandum-explanans* linkage and beyond, where the adequacy between the underlying reality and the activity of inquiry is assessed. Question set-up is also important, whether the most important questions are being asked, how questions are formulated, whether and how scientists understand the questions, and what kinds of answers are expected, sought, and employed once obtained [15]. Philosophers investigate how choices are made about the availability and valorization of data, what kinds and forms of data are present and made available, how gaps in data are conceived and approached, and what absences of data may mean [16].

1) The Scientific Method and Novel Discovery

One of the biggest methods questions in big data science is regarding the scientific method. Practitioners and philosophers wonder to what degree the traditional scientific method might still be relevant, valid, usable, and complementary to other methods. Philosophically, the issue is to determine the position of big data science methods relative to the traditional scientific method. The two primary concerns revolve around whether the scientific method has been superseded by big data science methods, and whether new kinds or forms of science, discovery, and knowledge are now available through big data conceptualizations and practices. There is an intuitive sense that novel discovery may be available, and different thinkers attempt to analyze and substantiate this claim. While there is more agreement among philosophers that the methods and practices of big data science are novel, there is no agreement on whether novel discovery is available, and even perhaps what constitutes truly novel discovery. However it is clear that there are some lower-level assumptions that may produce fallacies in thinking that can be easily avoided. One is that 'more is better;' that big data as 'more' data must automatically be better, and thus lead to more discovery [17]. Likewise, 'big data' does not necessarily mean 'smart data.' Further, there is a false tendency to accord big data undue importance, prominence, and status by being in awe of its sheer size, quantity, and reach. Another fallacy is, given the weight and historical position of the scientific method, thinking that it might be the only philosophical issue in big data science. Instead, there are many different levels of questions beyond the role and persistence of the scientific method.

Another key point in considering the status of the traditional scientific method is the role of the hypothesis. The obvious point is that maybe the hypothesis is no longer needed in an era of big data science where numerous experimental linkages can be determined at any later moment instead of inquiry having to be pre-specified. Science could become 'theory-free' without hypotheses leading inquiry, which on one hand could be a more objective approach to truth, but on the other might be too open, ephemeral, and unguided. However, there is a claim that theoretical assumptions persist and guide inquiry even if explicitly-specified hypotheses are not present. Further, that this can be detrimental to inquiry because these background assumptions and theories are not explicitly clarified, or shared by the group of investigators, while simultaneously researchers become more reliant on such assumptions. The result is that big data science may become overly theory-laden, and produce poor outcomes [18]. Thus, theory-ladenness is an important topic of investigation the Philosophy of Information.

Related to hypothesis is the consideration of causality. Here perhaps there has been an over-reliance on causality that has limited discovery [19, 20]. Big data science might help get beyond this by opening up new potential relational understandings of phenomena that can include causality, correlation, and other interrelations. A new tier of real-life problems can be tackled with big data science that are more systemic and complex, that are perhaps themselves characterized by interrelations that are not direct causal relations in the traditional sense. There might be episodic correlations that trigger situations, for example, that are not in the traditional structure of one cause producing one effect.

The bigger philosophical issue about whether new kinds and forms of science, discovery, and knowledge are being produced through big data methods will likely remain in debate. In the general sense, science continues to be a means of understanding reality. It is hard to support the stronger claims that big data science is a new mode of science, a new and different model for producing knowledge, and that new 'kinds' of knowledge are being produced. The weaker claims are more supportable, that the ways humans are conceiving and reacting to knowledge produced through big data science could be new.

C. Tools

After method, tools are likewise an important topic for investigation in the Philosophy of Information. Tools, particularly in the form of technology, have always been central to the practice of science. The role of tools and technology is a long-standing topic in philosophical investigation, with Democritus and Aristotle defining early positions in ancient Greek philosophy. It was immediately perceived that technology was fundamentally different from natural things. While Democritus thought that technology merely imitated natural things, Aristotle thought more expansively that artifacts can also go beyond the natural world to "*complete what nature cannot bring to a finish*" [21]. Other familiar examples of tools include Galileo's telescope (1611) and microscope (1625). Descartes notes that tools are required to "*arrive at the knowledge of nature*" [22], and comments in the *Dioptics* that "*there is no doubt that the inventions which serve to augment the power of sight are the most useful that could be made*" [23].

Perhaps the most important modern development in the conceptualization of tools, technology, and science is encapsulated in the notion of technoscience. The term was introduced by Belgian philosopher Hottois in 1984 to denote the type of science is that is technology-driven and conducted in a technological milieu [24, 25]. Even more than science and technology being connected, the idea is that they are deeply and inextricably linked. An older view was that science led to discovery, and then technology proceeded afterwards in application. Instead, the idea of technoscience positions science and technology in fundamental linkage, co-evolution, co-invention, and co-production. This can be seen in many contemporary fields, where it is impossible to separate the scientific from the technological, for example in big data science fields like nanotechnology, synthetic biology, and climate studies.

There is a sense among some philosophers that the technoscience discoveries of big data science are different, even if a full position of novelty cannot be substantiated. One approach employs technoscience to distinguish between 'traditional science' and big data science [26]. Another finds that reasoning occurs differently in the conduct of traditional science and technoscience, and that this could be helpful in knowledge production [27]. Another example highlights the difference between traditional science and technoscience: "*When an experiment is presented as scientific evidence which confirms or disconfirms a hypothesis, this agrees with traditional conceptions of science. When organic molecules are presented for their* ***capacity*** *to serve individually as electric wires that carry surprisingly large currents, this would be a hallmark of technoscience*" [28]. The focus of technoscience is on the ongoing enabling capacity of phenomena, not their behavior in one fixed situation.

A further dimension of technoscience is that it includes the property of technology as itself rapidly-changing; an obvious characteristic of a field like big data science. Thus technoscience, comprising the inherent dynamism of technology, suggests a position even farther from the traditional conceptualization of science as the somewhat static observation and analysis of reality. French philosopher Bachelard drew attention to this point, that the physical world of reality is constantly changing. Therefore, there could be a fallacy in discovery methods that attempt to approximate a constantly-changing reality, since this may not involve a concrete knowledge of things [29]. Bachelard was also a precursor to the ideas developed in technoscience in his examination of tools in the scientific discovery process and noting their deeply integrative role and lock-step evolution. For example, the invention of new tools like the telescope engendered new ways of thinking about discovery in astronomy, and their realization. Likewise, big data methods may be reconfiguring the conceptualization of discovery in big data science, and similarly facilitating new realizations.

The fast pace of technological development is already raising interesting philosophical questions about artificial intelligence (AI), in this context regarding discovery by artificial technological agents like computing algorithms and robotic aides. There is the fast-approaching and eventual possibility of non-human agency in discovery, and a potential moment of tools becoming more advanced than humans. Already the best entity for many jobs, including in big data science, is a machine and human operating together; with the machine handling the 95% of the routine repeatable work and the human the 5% of the work that constitutes exception cases and new thinking [30]. Automated scientific inquiry is well underway with both computer-based programs like deep-learning neural nets and machine learning algorithms; and embodied robotic lab assistants operating with much greater speed, precision, and accuracy than humans. A key shift has been that automated agents are not just facilitating but actually producing knowledge [31]. Automated scientific inquiry is thus yet another way in which big data science is shifting the traditional conduct and conceptualization of science.

D. Concepts

Beyond the class of questions raised by methods and tools, another important area to consider in the Philosophy of Information is concepts, both methods and tools at the conceptual level, and other concepts more directly. A slate of these kinds of conceptual issues and related questions is outlined in Table III for consideration at the Society for the Philosophy of Information's March 2015 workshop at University College London (http://socphilinfo.org/). The Seventh Workshop on the Philosophy of Information addresses "Conceptual challenges of data in science and technology." Several of the topics discussed in this paper such as causality, data provenance and proof standards, the traditional scientific method, and the definition of big data are included.

TABLE III. CONCEPTUAL ISSUES IN BIG DATA SCIENCE

Concept	**Philosophical Questions**
Causality	How should we find causes in the era of 'data-driven science'? Do we need a new conception of causality to fit with new practices?
Quality	How should we ensure that data are good enough quality for the purposes for which we use them? What should we make of the open access movement? What kind of new technologies might be needed?
Security	How can we adequately secure data, while making it accessible to those who need it?
Big Data	What defines big data as a new scientific method? What is it and what are the challenges?
Uncertainty	Can big data help with uncertainty, or does it merely generate new uncertainties? What technologies are essential to reduce uncertainty elements in data-driven sciences?

1) Representation

An important example of a concept in the Philosophy of Information is representation. Big data exists in a variety of physical forms, but human engagement with it is always via some sort of approximation, derivative, abstraction, or representation. This is because big data itself has no inherent holistic form (which is itself an important philosophical problem of existence and ontology) or inherent forms that are accessible to humans. Thus it is impossible to comprehend big data directly. Numerous questions arise then as to how accurate a particular representation is in capturing the underlying phenomenon. There is the philosophical notion of repticity (representational authenticity), which includes both the ontological issue of the degree to which a representation corresponds to the represented, and the epistemic issue of how it is to be known that the representation is accurate and the proof standard [32]. For example, in big data science, how is it measured and known that the correct abstracted summarized big data flows are being represented accurately on the higher-level executive dashboards that are the human-data interface?

Any representation is perhaps already a view and not a truly objective look at the whole of what is big data, even if the first task is to try to look at the data objectively without a frame. So far visual representation has been the main tool for representing data, but arguably other modes or multimodal representations might be more helpful and could be developed over time. Several philosophers investigate information visualization as a form of data representation [33], and the degree to which biases and other social factors may extend to the interpretation of big data in practice, for example in the field of personalized medicine health data visualization [34]. One philosopher characterizes visualization as an attempt of "*computer-aided seeing of information in data*" [1]. Information visualization has developed into a full-fledged field and large industry group, with a cornerstone annual conference, SIGGRAPH, the ACM special interest group on Computer GRAPHics and Interactive Techniques (http://www.siggraph.org/). Among other philosophical issues, information visualization raises the topic of aesthetics, and exists as an interesting case of where a scientific analysis tool has become artistic practice. Thinkers and practitioners from many disciplines wonder whether information visualization is a science, an art, both, or something new [35].

IV. WHAT IS THE PHILOSOPHY OF BIG DATA?

The Philosophy of Big Data is concerned with the foundations, methods, and implications of big data; the definitions, meaning, conceptualization, knowledge possibilities, truth standards, and practices in situations involving high-volume, high-velocity, high-variety data sets. Now having considered Information, and the Philosophy of Information, the current status of the disciple of the Philosophy of Big Data can be considered directly. The Philosophy of Big Data is emerging as a specific and distinct field. At least two journals have been founded in the last few years, Big Data & Society: Critical Interdisciplinary Inquiries (http://bigdatasoc.blogspot.com/p/big-data-and-society.html), and Big Data (http://www.liebertpub.com/overview/big-data/611/). Jim Harris, a data science consultant and blogger, has cited the need for data philosophers: "*Despite the fact that all we hear about is the need for data scientists, there is also a need for data philosophers*" [36]. A productive symbiotic relationship between big data scientists and philosophers is necessary for the development of the field. He references Kant's idea that perception without conception is blind, and that conception without perception is empty. Different kinds of blindness, conceptual and perceptual, should be investigated in big data science, for example avoiding the case of data fundamentalism, which is blindly believing in big data results.

Similarly, James Kobielus a big data evangelist at IBM, points out that as with statistics, there is no single version of the truth in big data science. Thus we should be critical of beautiful data visualizations and data-driven narrative stories [37]. Grady Booch, also at IBM, as a chief scientist, is concerned with the human and ethical aspects of big data science, and sees tremendous social benefits. However, most of the time the full life-cycle of data is not considered; which can give rise to the possible specter of ineffective legal controls [38]. One of the most seemingly dramatic approaches to big data privacy and security is that of the Harvard Personal Genome Project. In fact, the approach is not radical, but responds congruently to nature of the big data era. The Project's claim is no privacy protection for participants given the practical impossibility of securing individual information as even a few data elements may be correlated to impute identity.

Evelyn Rupert, editor of Big Data & Society, focuses closely on the philosophy of big data. She cautions against having normative relations to data, and re-creating traditional models which may be ineffective, such as inegalitarian hierarchies and other structures, in greenfield digital environments. We should be vigorous and continually questioning the role and use of big data in our lives, and realize that data can be performative; meaning influencing or engendering certain actions on our part as a result of our interacting with it. This is a Heideggerian stance; that we should maintain the right relationship with technology, seeing it empoweringly as an enabler, which prevents our potential enslavement by it [39]. As part of the continual questioning process in our relation with data, Ruppert reminds that any mode of interacting with big data is representation and not necessarily reality [40].

Perhaps one of the most recognized philosophers of big data at present is Rob Kitchin, with a 2014 book, *The Data Revolution: Big Data, Open Data, Data Infrastructures and Their Consequences* [41]. He points out that scant conceptual attention has been paid to data in and of themselves and examines to some degree how data are conceptualized. He outlines a binary view that data themselves either are neutral elements of reality or elements of social construction as any other such elements. The position is that data are a neutral measure of reality with no politics or agenda, and that people corrupt data and twist them to their own ends, not the underlying science itself. The other view is that data are epistemological units, socially constructed with all the bias, agenda, and political power that may be inherent to any social construct. Consequently, even how data are ontologically defined (well before they are used) is not a neutral, technical process, but a normative, political, and ethical one. This kind of binary view in known and similarly existing for science generally, debating whether science is objective or necessary subjective due to being socially constructed. It would be hard to substantiate that science, or data or big data science, could be independent of the thought system and the instruments underpinning their production [42]. Kitchin progresses the argument by proposing the idea of data assemblages that take into account these different influences explicitly, like place, subjectivities, political economy, institutions, regulation, and systems of thought.

A. Big Data and Complexity Science

There are significant hopes for big data science, for example that the field might help with today's seemingly intractable problems. One vision is to define the laws of complex systems the way that the laws of thermodynamics were enumerated in the industrial age. Perhaps big data science could identify the underlying principles that transcend the diversity, historical contingency, and interconnectivity of phenomena like financial markets, populations, ecosystems, war, pandemics, and cancer. An overarching predictive, mathematical framework for complex systems would, in principle, incorporate the dynamics and organization of any complex system in a quantitative, computable (e.g.; big data) framework [43]. Other scientists are less sanguine, for example, suggesting that the reality gap (map-territory modeling problem) is too large and that no data however big might be the fully relevant data set for the problem [44, 45]. Although certainly it is acknowledged that data are not the only input to a problem.

B. Justification: Why is a Philosophy of Big Data needed?

An obvious question arises regarding the justification for the philosophy of big data. Despite industry insiders calling for such a philosophy, a number of questions could be posed. Do we need a philosophy of data science? Is this something that would make a contribution or that big data scientists would actually be influenced by? Does it matter? How would we know or measure that it is helping? However, it is good to ask such questions, even if only to try establish the value of having a philosophy of big data. At its essence, philosophy is conceptual positions about how to make sense of the world, and certainly with big data as one of the strongest pervasive growing presences in the world, requires sense-making models and philosophical thinking about it at different levels. The reason that philosophy is important is that it provides the intellectual framework that shapes and justifies what kinds of questions are asked, how they are asked, how the answers are made sense of, and what is done with the resulting knowledge. Avoiding these kinds of philosophical questions weakens the intellectual rigor of a project and widens the scope of potential critique [46]. It is no longer the case that the domain of philosophy is the absence of data, while the domain of science is the presence of data, we are now at the point of applying the disciplines mutually for analysis and insight, with the appropriate interlinkage which is itself a philosophical exercise.

C. Philosophical Positions are already Inherent to the Conduct of Big Data Science

One reason to have an explicitly-considered philosophy is because even if it seems that philosophy is not involved, a default philosophical position may be being occupied. Scientists might wish to avoid the difficult and possibly seemingly irrelevant work of thinking through philosophical position by simply accepting the tenets of a dominant paradigm, or by operating at the level of methodology. Using the scientific method, for example, is a position that tries to put itself outside of philosophy, after the philosophy has been done, where scientists can proceed in a commonsensical, logical, and objective way to approach understanding the world that is largely beyond question. However, philosophical positions are inherent to the conduct of big data science and any science, whether scientists recognize this or not. A claim of having no philosophical position is a claim to the default position. There is an inherent ontology and epistemology to science fields as they develop, and also an inherent morality;

science has an ethics by default that should be addressed explicitly in responsible innovation in these fields [47].

V. Practical Example: Synthetic Biology

Now turning to applications, data-intensive science comprises many different fields of inquiry. A computational equivalent is emerging as a full-fledged field and accompaniment to nearly every area of science. Beyond science, this is also true in the humanities, for example with computational philosophy, topic-modeling (concept analysis) in literature archives, social network sentiment analysis, and the general notion of digital humanities. Some of the main categories of data-intensive science are Earth, Environment, and Natural Systems; Health and Biology; and Scientific Computing Infrastructure [48]. More specifically, these fields include atmospheric science, weather-forecasting, astronomy, chemical dynamics, and turbulence; complexity science, neuroscience, healthcare, biology, and ecology; computing and information networks, cloud-computing, and information publishing and dissemination; and advanced computing, artificial intelligence, machine learning, deep learning, and neural networks.

One such field, synthetic biology, is an important and quickly-expanding field of data-intensive science involving both advanced computing and biology. Synthetic biology also offers a full slate of potential philosophical concerns to demonstrate more concretely what big data philosophy is and how it might be used operationally. Further, not only are there numerous philosophical problematics, it is also exemplar of a field in which scientists themselves have become more heavily involved than in other fields at asking and considering the philosophical questions. This seems to be driven by necessity since the field is fundamentally about the question of life and making new kinds of life, and also a sense of ethical responsibility and self-policing that has been a strong development alongside the science. The field's activities are in the same model of the scientific community's self-established guidelines at the 1975 Asilomar Conference on Recombinant DNA. Thus synthetic biology stands as a premier example of an innovative data-intensive science field co-evolving with the philosophy of the field.

A central philosophical question raised in synthetic biology is whether it is all right to interfere with natural processes. Humans have always been manipulating the natural world, for example in plant and animal breeding. However the question with synthetic biology is whether it is just a better way of influencing the natural world as always, or whether it constitutes something fundamentally new. Perhaps synthetic biology is somehow different, producing a qualitative change with its precision-targeting and creation of new kinds of organisms and functionality. There has been an ongoing progression of increasing control over the natural world with crop-breeding, agriculture, genetically-modified organisms (GMO), and now synthetic biology. Philosophy may be able to help in considering new paradigms, orders of magnitude issues, and what constitutes a true ontological change. Likewise, there are concerns with *de novo* generation, like what it might mean to be making new biological organisms from scratch [49].

A full slate of philosophical problematics in synthetic biology has been outlined in the three main categories of ontology, epistemology, and ethics. Those relating to ontology or existence are fundamental, for example probing the nature of reality and existence, questioning the definition of "*What is life?*" One query is how much change in DNA would be required for a moment of speciation to create a sub-species or sufficiently different organism. Further, there is the philosophical question of what living machines and synthetic biology products are in and of themselves since this is a new kind of 'thing' that has not previously been part of reality.

Even the first ontological question of an agreed-upon definition of synthetic biology is not always an easy task, especially when like big data science, the field is in dynamic development. However one workable definition is that synthetic biology is the design and construction of new biological entities such as enzymes, genetic circuits, and cells, and the redesign of existing biological systems. Philosophically, an important unstated feature of the definition is that biology has been reconceptualized as an engineering medium instead of as exclusively a natural thing. Biology is a venue for human action-taking in unprecedented ways. Engineering principles are being applied to harness the many kinds of functionality inherent to biology, and also to chain biological functionality together in new ways. Biological functionality is being thought of modularly as fundamental components that can be assembled into new systems. Some of the main approaches in applying these biological engineering principles are metabolic engineering (bacteria produce fuel such as diesel fuel), extending *E. coli* capacity (yeast produce medicine), biomimicry (replicating biological function in synthetic systems), and *de novo* synthesis (creating new kinds of functionality) [50].

Developing taxonomies and classification systems is another important ontological concern where synthetic biology is rife with challenges. First is naming conventions. Different labs worldwide are generating different types of synthetic biological organisms, however a standard industry-wide naming and classification system does not yet exist. An obvious challenge is the parameters by which naming conventions should be developed. An early example from the J. Craig Venter Institute is '*Mycoplasma laboratorium,*' a partially synthetic species of bacterium derived from the genome of *Mycoplasma genitalium* [51]. The institute filed patents for the *Mycoplasma laboratorium* genome as the "minimal bacterial genome;" the minimally viable genome required for a bacterium (raising other long-standing ethical philosophical questions about the patentability of nature and generated nature that will not be addressed here). The point is the implied convention of replacing or appending a naturally-existing organism's biological name with the term *laboratorium* to denote its synthetic derivation. This particular naming system might not last, but these kinds of naming issues are likely to persist.

After naming, there is taxonomy, the issue of organizing and classifying modified and *de novo* plants and organisms into groups. One question is whether there should be a separate but analogous structure of Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species for synthetic biology. Or perhaps the existing taxonomic structures in 'classical' biology should be extended to accommodate synthetic biologically-generated organisms, for example demarcating natural, modified and *de novo* biology. A related issue is the potential inadequacy of traditional classification models in the wake of innovations like big data science. For example, the extremely wide dispersion of taxa in big data science areas like microbiome research has made it clear that the existing classification system is not appropriately suited to accommodating the new phenomenon. Certainly this is a known issue, that any classification system will necessarily have gaps and not correspond exactly with the analog messiness of the reality it is trying to model. In fact big data science could be helpful with these long-existing issues. First, it could be employed to measure these kinds of map-territory correspondence across fields, which is both a practical and philosophical issue. Second, the field could better match classification structures with reality, especially in inherently irregular areas like biology.

Related to naming and taxonomies is another ontological issue of how constellations of related organisms are to be organized. One issue is how to work with outdated paradigms that no longer hold, for example a distinction between living and non-living, and organic and inorganic [52]. In nanotechnology, scientists have already shifted their focus onto the *properties* of materials instead of their derivation as organic or inorganic. Philosophically, this is an important transition from fixed morphological definitions to ones that more dynamically focus on the capacities of what is being classified. This is a subtle and fundamental shift from not only thinking in the past to thinking in the future, but also from static states to dynamic states. Being attuned to future possibilities is a worldview that is more open-ended, generative, and creative than seeing reality in static structures. The French philosopher Simondon proposes exactly such a worldview, where organisms (like humans and possibly all forms of intelligence) can be seen as existing on a spectrum of capacity realization or individuation [53].

Beyond the ontological concerns in synthetic biology, there are likewise epistemological and ethical concerns. In epistemology, there are knowledge-related questions such as whether new fundamental kinds of knowledge are being developed, what might constitute new fundamental kinds of knowledge anyway, how we would know, what kinds of limits might exist on knowledge-seeking and its dissemination, and how the knowledge is to be employed.

There is a hands-on practical set of epistemological issues. One problem is scientists wondering how they can know that their methods are safe for themselves and beyond the lab; an ongoing concern in synthetic biology, epidemiology, and nanotechnology. Another problem is wondering whether synthetic biology might be able to create new biowarfare plagues that could overrun the world. Similar to the potential worry of world-destroying black holes being generated the large hadron collider at CERN, this situation is extremely unlikely, but scientists and the public need reassurance in ways that are tailored to make sense to the different audiences. Given the difficulty of developing any kind of organism in synthetic biology, it would not be likely to develop such harmful agents, especially ones that could have a wide range. Nature has been working billions of years itself to perfect some of the most pernicious bioplagues, and life proves continually resistant. Potential bioplagues are an epistemological, and ethical issue, and start to broach many of the usual kinds of practical ethical issues in the field. These include practitioner safety, accountability, responsibilities, unintended consequences, the right to do this work (is it playing God?), dual-use debate (technology can be used for both good and evil), and whether standard risk models are appropriate to handle these new situations. Finally, there are other philosophical issues regarding axiology, the according of value, such as what are the appropriate ownership and patentability models for synthetic biology products.

Overall this Synthetic Biology example has helped to demonstrate how the Philosophy of Big Data philosophy might be used in the daily practice of a certain field of big data science. The issues and modes of integrating philosophy with science are not restricted to Synthetic Biology, and could have a wide application across all areas of big data science and service development, whether in the context of scientific, governmental, corporate, or personal big data.

VI. Conclusions

The Philosophy of Big Data is conceived as the branch of philosophy concerned with the foundations, methods, and implications of big data; the definitions, meaning, conceptualization, knowledge possibilities, truth standards, and practices in situations involving very-large data sets that are big in volume, velocity, variety, veracity, and variability. In considering the impact of big data, it could be easy to adopt a critiquing and cautionary stance due to the nature of big data as being vast, intangible, unwieldy, and potentially unknowable. Worries range from the utmost philosophical, such as representational authenticity, to the extremely mundane, such as the utility of personalized recommendations. However, perhaps a more productive stance is taking on the challenge to create and define new conceptualizations and possibilities for human-data interaction. There is tremendous potential for the future of big data science and big data services in automating not just mechanical tasks but also possibly many classes of cognitive tasks.

The great hope is that the human-data relation can amplify human function well beyond the binary of the purchase transaction (buy-don't buy). With the aid of big data service, human function could be extended into data interactions that more meaningfully fulfill human emotional and intellectual needs, and produce new levels in the subjectivation possibility for both humans, and data entities. The endgame is mechanisms that allow humans and data entities to be more; to grow, learn, and contribute at a higher rate. Services that start to look to these levels are the ones at which a Philosophy of Big Data aims, and could help to engender many next generations of felicitous human-data relations. Overall a Philosophy of Big Data might helpful in conceptualizing and realizing big data science as a service practice, and also in transitioning to data-rich futures with human and data entities more productively co-existing in mutual growth and collaboration.

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