Minimal Information Structural Realism

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Abstract

This paper presents Minimal Information Structural Realism (MISR). MISR claims that information (signified by I) is an ontologically and epistemologically objective physical entity[1] (signified by R) and is perceived as, but not identical to, organization, form, or structure of nature (signified by S). There is a relatively significant body of literature claiming that the essential, if not fundamental, element of nature is information. Authors differ on the precise description of information conceived this way. However, they do agree that it would be a forming element in nature, a factor responsible for patterns observed in reality, apprehended through order, organization or structures. To express the fundamental ontological role of information in nature, a new kind of structural realism, or rather information structural realism (ISR), is needed. This paper is proposing exactly this in the form of minimal information structural realism (MISR). The basic claim of MISR is that *information is a foundation of reality and it is perceived or apprehended through patterns or structures*. This claim embodies basic intuitions regarding the role of information in nature. MISR is not associated with the structural realism SR of the ontic or epistemic kinds, and is only remotely related to the concept of information structural realism (ISR) defined by Floridi.

Keywords: Information, Information ontology, Structure, Structural Realism, Information Structural Realism

[1] Epistemic objectivity means that the object of knowledge is independent of the mind. Ontological objectivity means that the object is/exists as observer independent. See lecture at Google Academy by John Searle (2015) for this type of distinction. Of course, this division assumes the existence of the mind independent of reality.

Introduction

This paper presents Minimal Information Structural Realism (MISR). MISR claims that information (signified by I) is an ontologically and epistemologically objective physical entity[2] (signified by R) and is perceived as, but not identical to, organization, form, or structure of nature[3] (signified by S). The term minimal (M) is added to ISR, meaning that no other claims, epistemic, ontic, or others, are associated with MISR. MISR may be seen as a version of Structural Realism (SR). However, MISR goes beyond structures conceived in SR[4] and postulates that behind them lies information. MISR is not a claim about pancomputationalism though, along the views of, for example, Fredkin (1991), Lloyd (2007), or Muller (2008). The paper is not a comparison of MISR with SR but rather an explication of MISR and SR is providing solely the context for the discussion.

The paper is organized as follows. First, the basic claims of SR are reviewed. Second, the concept of information is discussed. Finally, the basic assumptions of MISR are explicated. Finally, the conclusion collects the claims formulated in the paper and suggests some areas for further work.

Structural Realisms (SR)

SR, as explicated in the works of Psillos (2004), Brading and Laundry (2006), Frigg and Votis (2010), Ladyman (2016), and many others[5], claims that nature is structural (roughly speaking because structure is what seems to be invariant in scientific models of nature; it is what survives theory changes). The two main currents in SR are ontic and epistemic. Ontic Structural Realism (OSR), as defined by Ladyman (1998) and French (1998), embodies the view that structure is the ultimate reality and ontologically basic. In the strong version of OSR structures are "all the way down" (Frigg and Vostis (2010). Epistemic Structural Realism (ESR), defined by Worrall (1989), claims that structures are all that we can and may know about nature. There can be more to nature than structures but ESR does not say what this "more" could be. The differences between ESR and OSR go much deeper but they are omitted here as having no importance for this discussion. Another version of SR that is interesting from the perspective of MISR is Information Structural Realism (ISR).

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[2] Epistemic objectivity means that the object of knowledge is independent of the mind. Ontological objectivity means that the object is/exists as observer independent. See lecture at Google Academy by John Searle (2015) for this type of distinction. Of course, this division assumes the existence of the mind independent of reality.

[3] In some structuralist papers the term 'form' is used exchangeable with 'structure'. For example Worrall writes ".. *There was continuity or accumulation if the shift, but the continuity is of form or structure*... "(Worrall, 1989, p. 117). Such examples may be found in other papers on structuralism.

[4]This concept of structure obviously assumes that it is a representational or abstract (or abstracted) structure, not nature itself.

[5] SR and related ideas extend well into last century and traces of it can be found in much earlier works (for example, see Ladyman (2016)).

ISR has been defined by Floridi (2004, 2010). It does not change basic SR_S claims, rather it admits that nature is structural, but structures are informational objects or information structures. Information structures supervene upon data (or data structures). Data structures, in order to be information structures, must have meaning, which in turn depends on the presence of the scient agent[6]. Elementary data structures form “infons” or “elementary information particles” (Floridi, 2010. At the core of ISR is the General Definition of Information (GDI) which describes the foundational assumptions behind data, infons, and information structures (a more detailed description of data and infons is given in the following sections). ISR, because of its epistemic claims, can be seen as a variant of ESR[7].

Information

Most of the definitions of information relate it to knowledge, belief, or a communication process (for example, see Burgin (2003), Capurro (2009), Floridi (2010) or Nafria (2010)). This makes information epistemically and ontologically subjective; information exists if someone recognizes it as such, it exists specifically in and for the mind of the receiver or an originator, or it exists when communicated (such as created, sent, and received). Epistemologically and ontologically subjective information is the one specified by General Definition of Information (GDI) elaborated by Floridi (2010) or information defined by Bar-Hiller and Carnap (1953), Brooks (1980),Loose (1998), Sveiby (1998), Dretske (1999), Casagrande (1999), Burgin (2003), and Lenski (2010), to list just a few examples. Shannon’s definition of information as being a measure of the probably density function (PDF) over some probability space (Shannon (1948), Shannon and Weaver (1964), Pierce (1968)) may have subjective or objective properties depending on how probability is defined (Gilles (2000)). If we accept Shannon’s information for what it is (a moment of (PDF)),we may think of it as some measure of patterns, which may be natural or implied. However, how Shannon’s information is related to other concepts of information is disputable (see, for example, the discussion of Shannon’s information by Shannon Weaver (1964), Pierce (1968), Cherry (1978), Casagrande (1999), Hidalgo (2015), Krzanowski (2016), and Schroeder (2017)). [8]This incongruence between Shannon’s information and other concepts of information creates significant interpretation problems in explaining the role and nature of information.

In recent decades, the perception of information as a rational or logical element of nature, or its founding or ontological principle, has become quite widespread in physics, cosmology,

[6] Dependence of informational structures on the mind gives to Floridi’s ISR a Berkeleyan touch, so it seems.

[7]The problem for SR is that the definition of structure and its ontological meaning are open; SR structure is often left unspecified (Vostis, 2010; Floridi, 2004), or assumed to be logical, physical, or mathematical in nature, or claimed that it is an information object of the sort defined in the OOP paradigm (Floridi, 2005), but there is no single version of a structure accepted in SR.

[8] For example, Hidalgo writes “…the interpretation of entropy and information that emerged from Shannon’s work was hard to reconcile both with the traditional use of the word information and with the interpretation that emerged from Boltzmann’s work” (Hidalgo, 2105, p. 15).

computing sciences, biology, and other sciences. Information seems to be a unifying concept connecting these diverse domains. The success of computing models of natural phenomena can be explained by postulating that computing models and nature share a common element – information (see for example Polak (2017)).

One may argue that the concept of information as an ontological element of nature goes back as far as the pre-Socratic Greeks and Ancient China (Curd (2011), Oldstone-Moore (2011)). However, it is safer to focus on the twentieth century authors; the incomplete, selective, and rather idiosyncratic list would include[9] Zuse (1970), von Weizsäcker (1970), Turek (1978), Wheeler (1982),Heller (1987, 2014), Collier (1989), Batenson (1979), Stonier (1990), Toffoli (1990), Thagard (2000), Barwise and Ethemendy (2000),Steinhart (2000), (Jadacki and Brozek 2005), Seife (2006), de Castro (2007), and Hidalgo (2015). These authors claim in some way or another that information is at the center of nature, as energy is, and is related somehow to structure of nature or its form. Collier (1989) writes, "Physical things have properties that give them a definite structure and causal capabilities. If information is an intrinsic property of physical objects, then it seems likely that it is contained in their physical structure" (p. 6). Hidalgo (2015) states, "Information…understood broadly as a physical order "and further"… information is not restricted to messages. It is inherent in all physical objects" (p. 6). Seife (2006) claims that "…there is something about information that transcends the medium it is stored in. It is a physical entity, a property of objects akin to energy or work or mass" (p. 57). Stonier (1990) writes that "…information exists… information has physical reality and constitutes an intrinsic property of the universe" (p. 12). Dodig-Crnkovic (2012) states "The universe is, from the metaphysical point of view, nothing but processes in structural patterns all the way down". Understanding patterns as information, one may infer that information is a fundamental ontological category" (p. 228).

For Hidalgo, Seife, and others, information is as real as any physical phenomena can be; it is objective, it is structural, and it is a property of the universe. Clearly, these authors are telling us that those seeing information only in an epistemic optic are missing something. With this view in mind, we are ready to propose MISR.

Why Minimal Information Structural Realism?

Presented here are two arguments for the fusion of the concepts of structuralism and ontological information –in a way, this composition is MISR. One argument is based on the conclusions from models of quantum mechanics (QM) and cosmology, while the other argument is referred to as incompleteness of epistemic definitions of information. Additional arguments in favor of MISR can be formulated, but these two seem to carry the most weight[10]. The arguments propose that interpreting natural structures as informational is consistent with the findings of

[9] Dates of publication refer to the edition not to the original date of publication of the work.

[10] Other arguments include the arguments from the philosophical tradition, scientific intuitions, and success of computing models in modeling diverse aspects of nature.

physical sciences and that epistemic interpretation of information and structures (as in ESR and ISR) is not sufficient for the description of properties of nature.

*Isomorphism of mathematical models of nature***.** The research in physics and cosmology provides evidence that different mathematical structures of natural phenomena support the same experimental results (Heller, 2014, p. 85). This would suggest that behind different mathematical models, or structures, there is an unchanging physical reality, and mathematical models are just reflections, or approximations, of this reality. Heller, a cosmologist and a philosopher, gives the example of how the evolution of quantum states is modeled by three different mathematical representations: those of Schrödinger, Heisenberg and Dirac. Heller (2014) writes:

> There is a proof that these (Schrödinger, Heisenberg, Dirac) mathematical models are unitary equivalent, meaning that they lead to the same empirical predictions. To say it differently, there is an isomorphism between these models with respect to all observables. Thus, it is not the case that one mathematical structure corresponds to something we would call the structure of the world. (p. 64)

Heller observes that, as these three models support the same experimental results, they must then refer to another invariant structure, to which we do not have access, but that is representing a true reality or is a reality in itself. Heller (2014) also writes, "This is not an exceptional situation in physics" (p. 65), meaning that multiple mathematical structures describing successfully the same physical phenomena exist, as well, in other areas of physics than just QM. Further, Heller (2009) writes that "…every (natural) structure has certain information; more constraints (by laws of physics) given structure imposes more information it contains. As the world is a structure, it contains certain information, or (we may say) the structure of the world encodes certain information" (p. 63). Still, in a different work, Heller (1995) observes that "…the modern physics suggests that the world does not have a structure but is a structure. This structure contains in itself certain information (or is information).Science decodes its fragments by fitting mathematical structures to the structure(s) of the universe"(p. 170). Heller (1987, 1963) as states:

> …even if a real world contain something more than a form, with the methods of modern physics we are unable to touch it: this something intangible escapes through gaps of the mathematical models and experiments…. If information may be conceptualized as constraining options, every law of physics is information, as it constrains nature. It may be suggested that the stuff of the world is information. However, following Shannon's definition of information, information is a structure and not what possibly can this structure fill in. In this view the structure of the world is an information encoded. The role of science is to break this code and reveal information. *(p. XX)*

Heller's proposition, therefore, is summarized as:

a) The universe (the world) is a structure.
b) The mathematical models (mathematical structures) of the universe represent this structure up to isomorphism[11] up to all observables. Mathematical structures approximate the world structure.
c) The structure of nature is behind the structures we conceive and this structure behind structures has the characteristics of, and may be represented as, information, or is information[12].
d) Such information is a physical phenomenon. It does not require a conscious observer or an originator to exist. It is ontologically objective.
e) The world can be conceptualized as a structure containing information. This information is ontologically objective.

Epistemic incompleteness. In epistemic definitions, information always supervenes on datum or data. The existence of data in addition to information is what may be called epistemic incompleteness. Epistemic incompleteness means that epistemic definitions of information recognize the necessary existence of something beyond epistemic information itself for the complete description of nature[13]. An exemplary case for epistemic incompleteness is offered by the GDI. In GDI, data are primary "stuff" of the universe and occur prior to information (Floridi, 2010, p.84). Data are denoted as "lack of uniformity", diaphora de re, didomena, or "a fracture in a fabric of being" (Floridi, 2010).Information forms structures composed of data in a certain, specific way that is meaningful to some observer. As Floridi (2010) writes, "…General Definition of Information (information is defined) in terms of data + meaning" (p. 83). Thus, information supervenes on data structures. In addition, between information structures and data, Floridi includes *infon* – an elementary particle of information; as Floridi (2010) writes, "the parallel with fundamental particles of physics the electrons, protons, neutron, photons, and so forth" (p. 85). Infon is a strange concept, as on one hand it is conceived to be similar to elementary, physical particles and objective ontologically, while, on the other hand, it has an epistemic, subjective quality.

The incompleteness arguments can be summarized in the following way:

[11] Heller interprets isomorphism following Weyl (1949, p. 25). The critical point Heller is making that the mathematical structures are not isomorphic to each other but only 'up to the empirical results". This means that they are different yet consistent with natural phenomena. This may only mean that they are not representing the phenomena simpliciter but its facet, or aspect.

[12] The essence of this argument is not that there are isomorphic structures but that there are isomorphic structures experimentally equivalent.

[13] It is interesting that data are usually considered to be ontologically objective entities. Thus, epistemic definitions of information (depending on data for their definition) indirectly admit the existence of ontologically objective component.

a) Epistemic information supervenes on data or/and infons.
b) Epistemic information for the description of nature requires an ontological component (data).
c) Ontological information (by definition) does not require any other concept for its definition. Ontological information has a more parsimonious definition of information than epistemic one.
d) Ontological information does not supervene on any other phenomena.
e) Ontological information is a more fundamental concept than epistemic information.
f) Ontological Information is better suited for description of natural phenomena.

Minimal Information Structural Realism

MISR combines intuitions about the structural nature of reality and the ontological and foundational role played by information. Structures in MISR are the invariant (natural) order behind the abstract structures of ESR or OSR. Information in MISR is not something awaiting to be recognized by a scientific mind, but rather an organizational principle pervading nature. This view of structures and information is not present in current strands of SR (ESR, OSR, and ISR).

MISR claims that information is an objective aspect of reality and it is perceived or apprehended through patterns or structures. No data and no infons are necessary to define what information is.

MISR is not associated with ESR and OSR directly, but it does not contradict them. MISR is somewhat related to the concept of Floridi's ISR, in that both ISR and MISR attribute importance to the role of information in nature, yet do so in different ways. Floridi's ISR claims that structures perceived in SR strands are informational structures, or can be interpreted as informational, similar to informational structures modeled by the Object Oriented Programming (OOP) paradigm (Floridi, 2004). MISR claims that structures in SR reflect, or approximate, the structure of nature that contains information.

Versions of MISR may support more nuanced versions of MISR along ontic, epistemic, mathematical, quantum, or computational perspectives. Of course, each of these versions of ISR must be refined and evaluated for its logical coherence and correspondence with the facts of physics[14]. In MISR, the relationship of structures to information is like the relationship of energy to work: energy is characterized by the ability to do work, and so information is the ability to form structures[15]. Such a definition of energy does not make it meta-physical, and such

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[14] One would have to mention the differences in the understanding of *realism* in SR and MISR. In SR, realism denotes the position of science and scientific theories vs. nature (realism vs. anti-realism). In MISR, realism denotes the objective nature of information. Both realisms, in further interpretations, do, however, converge on the same claim that there is an objective reality that we can study. Realism is a polysemic concept that splits various versions of scientific realism (see for example Chakravartty (2007)). It seems that MISR may add still another interpretations to what is real.

[15] Fundamental concepts in physics are often described by the way they manifest themselves. For example, the concept of energy is defined as a capacity to perform work or a capacity to cause movement. The concept of

a definition of information does not make it other-worldly, but rather makes it as physical as can be.

Conclusions and Open Issues

SR and MISR take two different, but not completely contradictory, views of nature and our knowledge of it. SR claims structures are what is or what can be known[16], but that they have nothing to do with information. In Floridi's ISR, information is epistemic and it emerges over structures composed of data. MISR sees structures that we conceive as representations, or approximations, of the structure of nature, which is what is invariant behind SR structures. This structure of nature may be thought of as information or composed of information.

One may ask, again, what is ontologically objective information? The best answer would be the one already given by an analogy to energy – information is a capacity to create order, form, or structure. While not a very clear explanation, fundamental concepts notoriously elude precise description just because they are, by definition, fundamental. Descriptions of fundamental concepts in SR (structures) or in ISR (data and infons) do not fare any better in clarity, yet they are missing what MISR offers: the power to explain isomorphism of mathematical models of physical phenomena and incompleteness of epistemic information.

One interesting line of further study would be to investigate information in the context of unobservable detectable and undetectable - the division of physical phenomena and entities splitting versions of scientific realism as pointed out by Chakravartty (2007). Further, assuming that information could be posited as unobservable detectable, it would be interesting to ask how this claim could be justified for information, if it could be justified at all.

But what if information is an unobservable undetectable?

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entropy is defined as lack of organization or, more abstractly, as the increased state space. Thus, defining information as a propensity or capacity to form structures seems to follow the same approach. As O'Connell (2016) observes: "The more basic a physical notion is the more difficult it is to describe in words".

[16] A big problem for SR is how structures in ESR and OSR are related to nature. This problem seems to be so far unsolved, despite many propositions.

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