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Floridi's Open Problems in Philosophy of Information, Ten Years After

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Abstract: In his article Open Problems in the Philosophy of Information (Metaphilosophy 2004, 35 (4)), Luciano Floridi presented a Philosophy of Information research programme in the form of eighteen open problems, covering the following fundamental areas: information definition, information semantics, intelligence/cognition, informational universe/nature and values/ethics. We revisit Floridi's programme, highlighting some of the major advances, commenting on unsolved problems and rendering the new landscape of the Philosophy of Information (PI) emerging at present. As we analyze the progress of PI we try to situate Floridi's programme in the context of scientific and technological development that have been made last ten years. We emphasize that Philosophy of Information is a huge and vibrant research field, with its origins dating before Open Problems, and its domains extending even outside their scope. In this paper, we have been able only to sketch some of the developments during the past ten years. Our hope is that, even if fragmentary, this review may serve as a contribution to the effort of understanding the present state of the art and the paths of development of Philosophy of Information as seen through the lens of Open Problems.

Introduction

In his programmatic paper *Open Problems in the Philosophy of Information* [Floridi 2004b] based on the Herbert A. Simon Lecture in Computing and Philosophy given at Carnegie Mellon University in 2001, Floridi lists the five most interesting areas of research for the nascent field of Philosophy of Information[1], containing eighteen fundamental questions. The aim of present paper is to address Floridi's programme

[1] The reader interested in the history of Philosophy of Information will find more background in the Handbook on the Philosophy of Information [Van Benthem and Adriaans 2008].

from a 10-years distance. What have we learned? What do we expect to learn in the future?

We can trace the origins of the programme back to 1999 when Floridi's book *Philosophy and Computing: An Introduction* [Floridi 1999a] appeared, immediately followed by the first shift towards information-centric framework in the article *Information Ethics: On the Philosophical Foundations of Computer Ethics*, [Floridi 1999b]. The development from the first, more concrete technology- and practice-based approach towards the abstract information-centric account is evident in the coming decade which will result in numbers of articles developing several strands of the programme declared in *Metaphilosophy* in 2004. Floridi has significantly contributed to the development of Information Ethics, Semantic Theory of Information, Logic of Information and Informational Universe/Nature (Informational Structural Realism) – to name the most important moves ahead.

Together with Floridi, a number of researchers have contributed, directly or indirectly to the advancement of the field and offered interesting solutions and insights into the nature of information, its dynamics and its cognitive aspects. In what follows we will try to list some of those contributions.

In 2008 Floridi edited the book *Philosophy of Computing and Information - 5 Questions* [Floridi 2008] with contributions by Boden, Braitenberg, Cantwell-Smith, Chaitin, Dennett, Devlin, Dretske, Dreyfus, Floridi, Hoare, McCarthy, Searle, Sloman, Suppes, van Benthem, Winograd and Wolfram. The last of five questions each of the distinguished interviewees answered was: "What are the most important open problems concerning computation and/or information and what are the prospects for progress?"

The special issue "The Philosophy of Information, its Nature and Future Developments," of *The Information Society: An International Journal*, 25(3) published in 2009, and edited by Luciano Floridi, addresses Floridi's Philosophy of Information and Information Ethics (Ess); the Philosophy of Information culture (Briggle and Mitcham); epistemic values and information management (Fallis and Whitcomb); information and knowledge in information systems (Willcocks and Whitley); starting with Floridi's introduction: The Information Society and its Philosophy.

The recent special issue of *Metaphilosophy*, [Allo, 2010], the same journal that published Floridi's program in 2004, was devoted to Luciano Floridi and the philosophy of information (PI) addressing issues of knowledge (Roush and Hendricks), agency (Bringsjord), semantic information (Scarantino and Piccinini; Adams), methodology (Colburn and Shute), metaphysics (Bueno) and ethics (Volkman) with an epilogue by Bynum on the philosophy in the information age. It gives good state of the art insights into the development of PI.

Luciano Floridi's Philosophy of Technology: Critical Reflections is presented in a special issue of Knowledge, Technology & Policy, Volume 23, Numbers 1-2 / June 2010, guest edited by Demir Hilmi [Demir 2010]. It contains several articles on PI, addressing informational realism (Gillies), contradictory information (Allo), epistemology of AI (Ganascia), perceptual evidence and information (Piazza), ethics of democratic access to information (da Silva), logic of ethical information (Brenner), the demise of ethics (Byron), information as ontological pluralism (Durante), a critique of Information Ethics (Doyle), pre-cognitive semantic information (Vakarelov), an argument that typ-ken (an amalgam of type and token) drives infosphere (Gunji et al.). The special issue ends with Floridi's comments.

Floridi's newly published book [2011] shows the up to date state of his view of the Philosophy of Information. It presents his substantial contributions to the research field and contains his widely known work which confirms the relevance of our account when it comes to Floridi's main contributions.

As we analyze the present state of the art of Philosophy of Information we try to situate the PI programme in the context of scientific and technological development that have been made last ten years and see their impact on the directions of PI research.

Open Problems Revisited

Floridi's *Open Problems* cover a huge ground with five areas: information definition, information semantics, intelligence/cognition, informational universe/nature and values/ethics. The task of assessment in one article of the progress achieved in one decade seems overwhelming. Nevertheless, let us make an attempt to re-examine the program and see how the listed questions look like today, without any pretense of completeness of the account. Even if fragmentary, this review may serve as a contribution to the effort of understanding the present state of the art and the paths of development. We will find many novel ideas and suggested answers to the problems arisen in the course of the development of Philosophy of Information. In order to elucidate the results of the progress made, we will present different and sometimes opposing views, hoping to shed more light on various aspects of the development and the future prospects.

I) **Information definition**

1. What is Information?

One of the most significant events since 2004 was the publishing of the Handbook on the Philosophy of Information, [van Benthem and Adriaans, 2008]. The Part B of the handbook, entitled Philosophy of Information: Concepts and History, include essays on Epistemology and Information (Dretske), Information in Natural Language (Kamp and Stokhof), Trends in Philosophy of Information (Floridi) and Learning and the Cooperative Computational Universe (Adriaans). From that part we can gain the insight in various facets of the concept, providing supporting evidence that nowadays concepts of information present a complex body of knowledge that accommodates different views of information through fields of natural, social and computer science. Or, as [Floridi 2005] formulates it, "Information is such a powerful and elusive concept that it can be associated with several explanations, depending on the requirements and intentions."

The discussion of the concept of information was shortly after Floridi's programme declaration in the Herbert Simon Lecture in 2001 a subject of a lively discussion, and [van Benthem and Adriaans, 2008] point to a special issue of the Journal of Logic, Language and Information (Volume 12 No 4 2003), [van Benthem and van Rooij, 2003], dedicated to the study of different facets of information. At the same time Capurro and Hjørland [2003] analyze the term "information" as a typical interdisciplinary concept, its role as a constructive tool and its theory-dependence. They review significant contributions to the theory of information over the past quarter of century from physicists, biologists, systems theorists, philosophers and library and information scientists. Concept of information as it appears in different domains is fluid, and changes its nature as it is used for special purposes in various theoretical and practical settings. As a result, an intricate network of interrelated concepts has developed in accordance with its uses in various contexts. In Wittgenstein's philosophy of language, this situation is described as family resemblance, applied to the condition in which some concepts within a concept family share some resemblances, while other concepts share others. Wittgenstein compares it to a rope which is not made of continuous strands, but many shorter strands bound together, no one running the entire length of the rope. There is no universal concept of information, but rather concepts held together like families or ropes. "The view epitomized by Wittgenstein's *Philosophical Investigations* is that meaning, grammar and syntactic rules emerge from the collective practices through the situated, changing, meaningful use of language of communities of users (Gooding, 2004b).” [Addis, et al., 2005]

Information can be understood as range of possibilities (the opposite of uncertainty); as correlation (and thus structure), and information can be viewed as code, as in DNA, [van Bentham and Martinez in HPI, p.218]. Furthermore, information can be seen as dynamic rather than static; it can be considered as something that is transmitted and received, it can be looked upon as something that is processed, or it can be conceived as something that is produced, created, constructed [Luhn 2011]. It can be seen as objective or as subjective. It can be seen as thing, as property or as relation. It can be seen from the perspective of formal theories or from the perspective of informal theories [Sommaruga 2009, p. 253]. It can be seen as syntactical, as semantic or as pragmatic phenomenon. And it can be seen as manifesting itself throughout every realm of our natural and social world.

The quest for a general concept of information that goes beyond family resemblances is still there as can be testified by several publications during the last decade [e.g. Lyre 2002, von Baeyer 2003, Roederer 2005, Seife 2006, Muller 2007, Kauffman et al. 2008, Brier 2008, Hofkirchner 2009, Davies and Gregersen 2010, Dodig-Crnkovic and Burgin 2011]. It seems legitimate to put the heuristic questions accordingly, ‘Can the static and the dynamic aspect of information be integrated when considering the static as result, and starting point, of the dynamic aspect? Can the objective and the subjective aspect be integrated when attributing degrees of subjectivity to objects? Can the thing, property and relation aspects be integrated when elaborating on transformations between them? Can the formal and the informal aspect be integrated when postulating an underlying common nature parts of which are formalizable while other parts are not? This is similar to Ludwig von Bertalanffy’s idea concerning the use of mathematical tools in his General System Theory [see Hofkirchner and Schafranek 2011]. Can the syntactical, semantic and pragmatic aspects be integrated when based upon a unifying semiotic theory? Can the specific aspects be integrated when resorting to evolutionary theory and identifying each information manifestation on a specific level of evolution?’

One of the explicitly dedicated approaches towards unity in diversity is that which is connected to the term “Unified Theory of Information” (UTI). While the question of whether or not a UTI is feasible was answered in a controversial way by [Capurro, Fleissner and Hofkirchner 1999], Fleissner and Hofkirchner tried to lay the foundations for a project of unification reconciling legitimate claims of existing information concepts underlying science and technology with those characteristic of social sciences, humanities, and arts (Fleissner and Hofkirchner 1996 and 1997). They have been doing so by resorting to complex systems theory.

In this context it is important to mention the contribution of the FIS (Foundations of Information Science) network that "from its very beginnings in early 90's" presented "an attempt to rescue the information concept out from its classical controversies and use it as a central scientific tool, so as to serve as a basis for a new, fundamental disciplinary development – Information Science." [Marijuan 2010] http://fis.icts.sbg.ac.at/c_1.html

Among initiatives with the aim to work towards a modern concept of information, a workshop entitled Information Theory and Practice has taken place in 2007, http://www.isomorph.it/science/duino2007 at Duino Castle, focusing on the difference between syntactic and semantic information.

In 2008, a project was started in León, Spain, aiming at the illumination of the concept of information. Its working principle is the mosaic window of the Cathedral of León. That's why it is named "BITrum" (after the Latin "vitrum") [Díaz Nafría and Salto Alemany 2009].

"Towards a New Science of Information" was the motto of the Fourth International FIS Conference held in Beijing in 2010, see http://www.sciforum.net/conf/fis2010. The proceedings of the conference will be published in a special issue of the journal triple-c.

In [Burgin, 2010], an essentially new approach (called parametric definition) is proposed to solve the problem with the definition of information.

Besides already mentioned information types, additional distinction ought to be made between the symbolic and sub-symbolic information, as well as conscious and sub-conscious information [Hofstadter, 1985], seen from a cognizing agent's perspective. The world modeled as informational structure with computational dynamics, presents proto-information for an agent [Dodig Crnkovic Entropy 2010] and it affects an agent's own physical structures, as not all of functions of our body are accessible for our conscious mind. This process of information communication between an agent and the rest of the world goes directly, subconsciously, sub-symbolically or via semiosis – sense-making information processing. In this approach, information undergoing restructuring from proto-information in the world to meaningful information in an agent on several levels of organization is modeled as purely natural physical phenomenon. Cognitive functions of an agent, even though implemented in informational structures, are not identical with structures themselves but present their dynamics that is computational processes.

2. What is the dynamics of information?

[Floridi, 2008c] gives the following explanation:

"By "dynamics of information" the definition refers to:

i) the constitution and modeling of information environments, including their systemic properties, forms of interaction, internal developments, applications etc.;

ii) information life cycles, i.e. the series of various stages in form and functional activity through which information can pass, from its initial occurrence to its final utilization and possible disappearance; and

iii) computation, both in the Turing-machine sense of algorithmic processing, and in the wider sense of information processing. This is a crucial specification. Although a very old concept, information has finally acquired the nature of a primary phenomenon only thanks to the sciences and technologies of computation and ICT (Information and Communication Technologies). Computation has therefore attracted much philosophical attention in recent years. "

The reader interested in the development of the field of Dynamic of Information prior to Open Problems, such as seminal work by [Dretske, 1981] and [Bairwise and Seligman 1997] is referred to the Handbook on the Philosophy of Information [Van Benthem and Adriaans 2008], [Burgin 2010] or [Floridi 2011]. Abramsky's [2008] contribution in the same Handbook connects information, process and games (representing the rules or logic) in the attempt to develop "fully-fledged dynamical theory".

Van Benthem's new book *Logical Dynamics of Information and Interaction*, [2011] provides answers to the question of information dynamics within a framework of logic developed as a theory of information-driven rational agency and intelligent interaction between information-processing agents. Van Benthem is connecting logic, philosophy, computer science, linguistics and game theory in a unified mathematical theory which provides dynamic logics for inference, observation and communication, with update of knowledge and revision of beliefs, changing of preferences and goals, group action and strategic interaction in games. The book includes chapters on logical dynamics, agency, and intelligent interaction; epistemic logic and semantic information; dynamic logic of public observation; multi-agent dynamic-epistemic logic; dynamics of inference and awareness; preference statics and dynamics; decisions, actions, and games; processes over time; epistemic group structure and collective agency computation as conversation; and rational dynamics in game theory. Van Benthem explores consequences of the 'dynamic stance' for logic as well as for cognitive science in a way which smoothly connects to the programme of Philosophy of Information, building its necessary logical basis.

Yet another answer to the question of information dynamics is given by Mark Burgin in his article *Information Dynamics in a Categorical Setting* which presents *"a mathematical stratum of the general theory of information based on category theory. Abstract categories allow us to develop flexible models for information and its flow, as well as for computers, networks and computation. There are two types of representation of information dynamics in categories: the categorical representation and functorial representation. Properties of these types of representations are studied. (...) Obtained results facilitate building a common framework for information and computation. Now category theory is also used as unifying framework for physics, biology, topology, and logic, as well as for the whole mathematics. This provides a base for analyzing physical and information systems and processes by means of categorical structures and methods."* [Dodig Crnkovic and Burgin 2011]

Similarly built on dual-aspect foundations is info-computationalism, ICON [Dodig-Crnkovic 2006 - 2010]. It relates to Floridi's program for PI, taking the pancomputational stance as a point of departure. With the universe represented as a network of computing processes at different scales or levels of granularity, information is a result of (natural) computation. Adopting informationalism, (Informational Structural Realism) which argues for the entire existing physical universe being an informational structure, [Floridi 2008], natural computation can be seen as a process governing the dynamics of information. In a synthesis of Informationalism and Computationalism, information and computation are two complementary and mutually defining ideas. [Dodig Crnkovic 2010]

Communication is a special type of computation. Bohan Broderick [2004] compares notions of computation and communication and arrives at the conclusion that they are not conceptually different. He shows how they may be distinguished if computation is limited to a process within a system and communication is an interaction between a system and its environment.

Burgin [2005] puts it in the following way:

"It is necessary to remark that there is an ongoing synthesis of computation and communication into a unified process of information processing. Practical and theoretical advances are aimed at this synthesis and also use it as a tool for further development. Thus, we use the word computation in the sense of information processing as a whole. Better theoretical understanding of computers, networks, and other information-processing systems will allow us to develop such systems to a higher level.

Close to info-computationalism (ICON) is the view that conceives informational dynamics as processes of self-organization. Whenever self-organizing systems in their behavior relate to the environment, they create information, that is, they rather generate information than process it and are thus information-generating systems [Hofkirchner 2010]. This concept might be called "emergent information". The difference to info-computationalism lies in the dynamics that is assumed as background. While info-computationalism regards any natural process that can be described by a definable model as computation, which is equal to information processing, in the "emergent information" approach only self-organization processes are deemed to produce information.

The triple-c model developed in the context of emergent information finds information generation in a series of orderly concatenated different manifestations: first comes cognition (the first "c") which refers to the information generation of a self-organizing system vis-á-vis its environment that is unspecified; the coupling of cognitive processes of at least two self-organizing systems yields then communication (the second "c"); and sustainable communicative processes lead to cooperation (the third "c") of co-systems for the sake of a commonly established meta- or suprasystem of which the co-systems are elements [Hofkirchner 2010]. In a less-than-strict-deterministic way cooperation feeds back to communication as communication does to cognition. That's the basic dynamics of emergent information.

In the ICON scheme [Dodig-Crnkovic, 2010 Entropy], the recurrent theme is the information/computation as the underlying structure/process. Information is fundamental as a basis for all knowledge and it's processing characterizes all our cognitive functions. In a wider sense of protoinformation it represents every physical/material phenomenon.

3. Is a grand unified theory of information (GUTI) possible?

There are several approaches that make such a claim.

Among the prominent groups working on unification, Unified Theory of Information (UTI) Research Group - Association for the Advancement of Information Sciences can be mentioned. http://uti.at/projects.html

UTI Research Group "aims at the advancement of reflection and discourse in academia and society about the role of information, communication, media, technology, and culture in society. It works for building a better understanding and for dialogue in information science, communication and media studies, and science and technology studies (STS). It is interested in advancing critical ideas, approaches, methods, and research that are needed for establishing a global sustainable information society." UTI Research Group publishes the tripleC journal supporting transdisciplinary research on information, communication, media, technology, and culture. http://www.triple-c.at/index.php/tripleC

Hofkirchner's UTI is about self-organizing systems (from the most primitive physical system to the social systems) that for themselves (in the case of cognition) or in interaction with other self-organizing systems (in the case of communication) or as part of higher-level self-organizing systems (in the case of cooperation) generate information and make use of it. And it is about artificial devices like the Turing machine computers that contribute to information generation not by organizing themselves (there is no self in the machine) but by being instrumental to the overarching social self-organization.

One of the unified theories, the info-computational framework, ICON [Dodig-Crnkovic 2011] is characterized by two basic ontological principles: information (structure) and computation (process). ICON provides a unifying generative scheme useful for the conceptualization of the range of phenomena from inanimate physical objects to cells, organisms, cognizing systems and ecologies offering new conceptualization of the nature of structures and dynamics of informational phenomena. We will come back to this approach in the discussion of informational universe/nature.

According to the current idea of computationalism (natural computationalism, pancomputationalism), not only machines are capable of computing, but any dynamic behavior of physical systems can be interpreted as computation, including the dynamics of biological systems. See [Babaoglu, et al. 2005] on self-organizing self-star/self-★ models – self-★ stands for self-organization, self-configuration, self-optimization, self-healing, self-protection, self-explanation, and self/context-awareness – applied to information-processing systems. Scheutz [2002] argues for this new kind of computationalism applied in the computational theory of mind explaining the nature of intentionality and the origin of language.

Kampis in his book *Self-Modifying Systems in Biology and Cognitive Science: A New Framework For Dynamics, Information, and Complexity* describes the computational nature of those systems [Kampis, 1991] that today are part of the new organic computing field. http://www.organic-computing.org/

It is important to recognize the paradigm shift in the thinking about structures and functions of living organisms that traditionally were considered to form a domain *qualitatively different* from computers. The difference between the present-day computing and Turing-type model of computation lies *in the role of context* of a given system. The Turing machine is *context-independent*, and computes a function *in isolation* from the outer world. However, self-organizing organisms are essentially *open and coupled* to the environment. [Dodig-Crnkovic, Entropy]

The Turing Machine model is not the most expressive model for the type of processes going on in living organisms. [Dodig-Crnkovic, M&M] Understanding biology in informational terms leads to increased understanding of all structures in the living world as *scale-independent networks*. *Interactions* within those networks are essential for the formation and maintenance of biological structures on different levels of organization.

Burgin [2010], in his new book *Theory of Information. Fundamentality, Diversity and Unification*, offers an approach to unification based on a synthesis of concepts of information describing processes in nature, technology, and society, with the main insights from information theory. He calls his approach a General Theory of Information [Burgin 2011]:

The general theory of information is a synthetic approach, which organizes and encompasses all main directions in information theory. It is developed on three levels: conceptual, methodological and theoretical. On the conceptual level, the concept of information is purified and information operations are separated and described. On the methodological level, it is formulated as system of principles, explaining what information is and how to measure information. On the theoretical level, mathematical models of information are constructed and studied.

Besides General Theory of Information, Burgin [2010] addresses Statistical Information Theory, Semantic Information Theory, Algorithm

Information Theory, Pragmatic Information Theory and Dynamics of Information.

Though, prima facie, Brier's "Cybersemiotics" does not appear to be a theory of information – in particular, if you consider the subtitle of his book from 2008 which runs "Why information is not enough!" – it is, among others, an attempt to find common grounds of information processes, at least, in the living world. In a recent description he writes (Brier 2010, pp. 1902-1903):

The integrative transdisciplinary synthesis of Cybersemiotics starts by accepting two major, but not fully explanatory, and very different transdisciplinary paradigms: 1. The second order cybernetic and autopoietic approach united in Luhmann's triple autopoietic system theory of social communication; 2. The Peircean phaneroscopic, triadic, pragmaticistic, evolutionary, semiotic approach to meaning, which has led to modern biosemiotics, based in a phenomenological intersubjective world of partly self-organizing triadic sign processes in an experiental meaningful world. The two are integrated by inserting the modern development of information theory and self-organizing emergent chemico-biological phenomena as an aspect of a general semiotic evolution in the Peircean framework.

Like UTI and ICON approaches Brier's Cybersemiotics is critical of mechanicism that either neglects meaning and related phenomena or is reductionistic and levels them down. However, Brier connects the mechanistic approach to the term "information", because Shannon and Weaver and Wiener and Schrödinger's definition that in his view is prototypical for the mechanistic approach is widely accepted in natural and technical sciences (Brier 2011, p. 1914). Despite that he construes an ontological hierarchy ("heterarchy") of different levels across which information processes and meaning can develop (Brier 2008, p. 381): *"Across levels, various forms of causation ... are more or less explicit (manifest). This leads to more or less explicit manifestations of information and semiotic meaning at the various levels of the world of energy and matter."*

Impact of those new theories on the development of Philosophy of Information will be visible in the years to come.

II) **Information Semantics**

4. The data grounding problem: How can data acquire their meaning?

Floridi, who together with Taddeo [Taddeo & Floridi, 2005 & 2007] contributed to the research on the data grounding problem, explains the situation in the following way: *"Arguably, the frame problem (how a situated agent can represent, and interact with, a changing world satisfactorily) and its sub-problems are a consequence of the data grounding problem [Harnad 1993], Taddeo and Floridi [2005]). In more metaphysical terms, this is the problem of the semanticisation of being and it is further connected with the problem of whether information can be naturalised."* [Floridi, 2008c]

The data grounding problem can be related to the two kinds of information, symbolic (language) and sub-symbolic (signals) and the world as proto-information, [Dodig-Crnkovic 2010, 2009]. Within pragmatic tradition, meaning is the result of use, or more generally, meaning is generated through the interaction of an agent with the world, including other agents. [Dodig-Crnkovic, 2010; Dodig-Crnkovic and Müller 2010] Data semantics (as especially evident in computer science and cognitive informatics) is therefore defined by the use of the data. Symbols are grounded in sub-symbolic information through the interactions of an agent.

This is in line with the praxical solution proposed by Taddeo and Floridi [2007] in form of Action-based Semantics with the simple basic idea that initially, the meanings of the symbols generated by an agent are the internal states of the agent which are directly correlated with the agents actions.

On the fundamental level, quantum-informational universe performs computation on its own, Lloyd [2006], Vedral [2010]. Symbols appear on a much higher level of organization, and always in relation with living organisms/cognizing agents. Symbols represent something for a living organism; they have a function as carriers of meaning. (See Menant's article in [Dodig-Crnkovic and Burgin 2011]).

As already pointed out, there are two different types of computation and both are implemented in a physical substrate: sub-symbolic and symbolic computation. Douglas Hofstadter has addressed the question of symbols formed by other symbols or sub-symbols in his book *Gödel, Escher, Bach: An Eternal Golden Braid* from 1979. Interesting to notice is that in the fields of Artificial Intelligence and Cognitive Science similar suggestions for the symbol grounding problem solutions are proposed by number of researchers, from Harnad [1990] to Ziemke [1999]. Smolensky presents a way of integration of connectionist ('neural') and symbolic computation, addressing computational, linguistic, and philosophical issues in [Smolensky, P. and Legendre, G. 2006].

Søren Brier in his *The Cybersemiotic Framework as a Means to Conceptualize the Difference between Computing and Semiosis* in [Dodig-Crnkovic and Stuart, 2007] offers a critical view which he also defends in his book *Cybersemiotics. Why Information Is Not Enough!*, [2008] in which he argues that first-person semiosis cannot be captured by info-computational models alone. Semiosis is a sign process which includes production of meaning, and computation is assumed to be adequately modeled by Turing machine. However, recent developments in the fields of cognitive computing and cognitive informatics involve much more complex info-computational architectures.

5. *Truth problem: How can meaningful data acquire their truth value?*

6. *Informational semantic problem: Can information theory explain meaning?*

Based on scientific tradition, information semantics can be related with system modeling [Dodig-Crnkovic 2005] and model validity [Dodig-Crnkovic 2008]. Truth might be ascribed to meaningful data organized into information in the sense of "correct well-formed information" within a coherent theoretical framework, implying that the data are correctly obtained, transmitted and stored, that they have not been corrupted in communication or storage or used inappropriately. Such correct data might be called "true data" but that is not the usual terminology in sciences and technology.

As knowledge is constructed from information, in order to provide a guarantee for knowledge to be true, Floridi proposes a new concept of Strongly Semantic Information [Floridi 2004c], which requires information to be true and not only well formed and meaningful data. Adriaans [2010] presents an interesting critique, claiming that Floridi's theory of semantic information as well-formed, meaningful, and truthful data is *"more or less orthogonal to the standard entropy-based notions of information known from physics, information theory, and computer science that all define the amount of information in a certain system as a scalar value without any direct semantic implication."* Even Scarantino and Piccinini in their article *Information Without Truth* for the special issue of *Metaphilosophy* [Allo 2010] remind that *"the main notions of information used in cognitive science and computer science allow A to have information about the obtaining of p even when p is false."*
Adriaans defends the position that *"the formal treatment of the notion of information as a general theory of entropy is one of the fundamental*

achievements of modern science that in itself is a rich source for new philosophical reflection. This makes information theory a competitor of classical epistemology rather than a servant." Chaitin in [Dodig-Crnkovic and Stuart] argues for the similar position.

According to Adriaans, information theories belong to two programs, empirical/Humean school and transcendental/Kantian school. Floridi's Strongly Semantic Information belongs to the transcendental program. Empirical approaches (such as those proposed by Shannon, Gibbs and Kolmogorov) present mathematical tools for selection of "the right model given a set of observations." While classical epistemology studies truth and justification, theory of information is based on model selection and probability. Floridi's philosophy, according to Adriaans analysis, incorporates selected notions from information theory into a classical research framework, while *"information theory as a philosophical research program in the current historical situation seems much more fruitful and promising than classical epistemology."*

This sounds like a convincing diagnosis. What Floridi's program finally aims at is to provide the basis for understanding of knowledge, truth and justification in terms of information (and I would add, necessarily also in terms of its complementary notion of computation). At some point all high level concepts (truth, justification) will be required to be translated into low level (info-computational level); in much the same way as symbolic cognition and subsymbolic cognition must be connected in order to be able to reconstruct the mechanisms that produce meaning.

On the other hand, Sequoiah-Grayson [2007] defends Floridi's theory of Strongly Semantic Information *"against recent independent objections from Fetzer and Dodig-Crnkovic. It is argued that Fetzer and Dodig-Crnkovic's objections result from an adherence to a redundant practice of analysis. (..) It is demonstrated that Fetzer and Dodig-Crnkovic fail to acknowledge that Floridi's theory of strongly semantic information captures one of our deepest and most compelling intuitions regarding informativeness as a basic notion."*

Nevertheless, even so, I would agree with Adriaans line of reasoning about the necessity of consequently relying on the fundamental framework of theory of information instead of a mix of classical epistemological and new information-theoretical concepts.

7. Informational truth theory: Can a theory of information explain truth?

Theory of information can explain truth as info-computational phenomenon, even though truth is not absolute, but represents our best present knowledge, within a given framework, as Adriaans suggests:

"Based on contributions of philosophers like Popper, Kuhn, Feyerabend, Lakatosh, Stegmuller, and Sneed in the middle of the twentieth century the common view among scientist is that scientific theories never can claim to be true definitively. What we can only do is try to find and select the best theory that fits the data so far. When new data are gathered, the current theory is either corroborated or, when the data are in conflict with the theory it has to be revised. The best we can reach in science is provisional plausibility. This is effectively the position of mitigated skepticism that is defended by Hume. This methodological position fits perfectly with the recent insights in philosophy of information, notably the theory of general induction that has been initiated by Solomonoff and his theory of algorithmic probability which is a cornerstone of modern information theory."

Naturalized epistemology [Dodig-Crnkovic, 2007], and [Dodig-Crnkovic 2006] describes the evolution of increasingly complex cognitive capacities in organisms as a result of interactive information processes where information is more concerned with *meaning* for an agent than with *truth,* as meaning is directly related to *agency*. Knowledge is typically distributed in a system of agents in a community of practice (interacting network of agents). Agency in the natural world is typically based on incomplete knowledge, where probabilities in agents models govern actions. Being internalized by an agent, data become information, in the context of the agent's experiences, habits and preferences. All of it is implemented in an agent's bodily structures (including brain where applicable) and determines its interactions with the world. Adaptive structures of agents in networks act as memory of the past development, and represent their learning history. This makes the relationship between information and meaning natural. Meaning governs an intelligent agent's behavior, based on data structured to information and further structured to knowledge that in interaction with the world results in agency. Truth is arrived at first in the interaction, based on propositional knowledge, between several agents (inter-subjective consensus about knowledge) or in the relationship between different pieces of propositional knowledge that an agent possess and can reason about. In the sense of Chaitin's "truth islands" [Chaitin 2003] some well-defined parts of reality can be organized and systematized in such a way that truth may be well-defined within those sets, via inter-agent communication. For an agent, meaning is more fundamental phenomenon than truth, and both must be possible to express in info-computational terms

"Within the context of information theory, the problem of founding knowledge as true justified belief is replaced by the problem of selecting the optimal model that fits the observations." Adriaans [2010]

From the everyday experience we know that we act based on knowledge we judge as plausible and which may be true or not. The underlying fundamental debate about certainty and probability is discussed by Fallis [2002], in the analysis of probabilistic proofs and the epistemic goals of mathematicians.

As uses for information can be many, in different contexts and for different agents, Patrick Allo in [Dodig Crnkovic and Stuart 2007] addresses the problem of formalizing semantic information with logical pluralism taken into account. Benthem's view is that logical pluralism is one of several ways of broadening the understanding of logic and its development. [Benthem 2008]

III) **Intelligence/Cognition**

8. Descartes' problem: Can cognition be fully analyzed in terms of information processing at some level of abstraction?

An example is Wang's Cognitive Informatics [Wang 2010] which shows even how this can be done in practice at some level(s) of abstraction. According to its founder, Yingxu Wang:

"Cognitive Informatics (CI) is a transdisciplinary enquiry of cognitive and information sciences that investigates the internal information processing mechanisms and processes of the brain and natural intelligence, and their engineering applications via an interdisciplinary approach." [Wang 2007]

This transdisciplinary research builds on the results from computer science, computer/software engineering, systems science, cybernetics, cognitive science, knowledge engineering, and neuropsychology, among others. Applications of CI include cognitive computing, knowledge engineering, and software engineering. The theoretical framework of CI links the information-matter-energy model, the layered reference model of the brain, the object-attribute-relation model of information representation in the brain, natural intelligence, autonomic computing, neural informatics, human perception processes, the cognitive processes of formal inferences, and the formal knowledge systems. In order to provide coherent formal framework for CI, new descriptive mathematical formalisms of Concept Algebra, Real-Time Process Algebra and System

Algebra have been developed. Here as well as in [van Benthem, 2008] it is evident that adopting information as a new fundamental principle calls for a change in formal approaches in logic, mathematics, model-building and understanding of their cognitive functions.

According to the triple-c model of Hofkirchner's UTI cognition is a manifestation of information, that is, cognitive processes are those types of information processes that perform the function of relating of a self-organizing system to some event or entity in its environment. When that system enters such a relation, it generates information. It is important not to forget that "cognition" in this context is not only meant for human systems but for living systems and material systems as long as they self-organize. The model concedes cognizability to non-human systems too, albeit in different degrees according to the evolutionary stage they represent. In terms of complexity, "cognizability" refers just to the dimension of solitary systems, that is, individual phases of metasystem transitions or elementary levels of suprasystem hierarchies.

The point, however, is that cognition in UTI is an emergent process, a less-than-deterministic process the outcome of which is the generation of information that cannot be reduced to some perturbation of the system or some input in the system or some algorithmic information processing inside the system because it constitutes a leap in quality. Thus Turing machine computation is not able to provide a model of natural or human information generation.

Even info-computational approach ICON [Dodig-Crnkovic Naturalized epistemology, 2007], and [Dodig-Crnkovic, 2009 and 2010] analyzes cognition in terms of information structures and processes. Cognition is understood as self-organized hierarchy of information processing levels in a cognizing agent. The lowest level is proto-information, the physical world as information. Naturalized epistemology [Dodig Crnkovic 2007] argues that all cognition is embodied and all mental activity arises as an emergent phenomenon resulting from a brain-body interaction with the environment.

9. *Dennett's reengineering problem: Can natural intelligence be fully analyzed in terms of information processing at some level of abstraction?*

Even here, the natural intelligence is based on a complex hierarchy of levels of information processing architecture. Intelligence (the capacity to acquire and apply knowledge) is closely related to cognition (high level functions carried out by the human brain, including speech, vision, attention, memory, and executive functions such as problem-solving and self-monitoring). [Wang 2009] defines abstract intelligence in the following way: *"In the broad sense, abstract intelligence is any human or system ability that autonomously transfers the forms of abstract information between data, information, knowledge, and behaviors in the brain or systems."*

In the field of AI, behaviors are important, so the chain data-information-knowledge ("information" here used in a restricted sense) ends with behavior and not with wisdom as was earlier proposed by Stonier (1997). Wisdom may be interpreted as a state of information that allows for successful behavior of the human system.

One of the fundaments of intelligence is logic. As we are learning about intelligence, natural and artificial, we also learn about logic. Here is Van Benthem's description of the state of the art:

"The view that logic is really only about consequence relations may have been right at some historical stage of the field. It is also what we all write in textbooks to have a slogan for beginning students. But frankly, it seems a view that has been patently inadequate for a very long time. Since the 1930s, modern core logic has been about at least two topics: valid inference, yes—but on a par with that, definability, language and expressive power. In fact, many of the deep results in logic are about the latter, rather than the former aspect: linked with Model Theory, not Proof Theory. And to me, that definability aspect has always been about describing the world, and once we can do that, communicating to others what we know about it. In fact, there is even a third pillar of the field, if we also count computation and Recursion Theory. Maybe it is high time we adjusted our self-image to reality." [Benthem 2008]

This new emerging broader understanding of logic with "scope and agenda beyond classical foundational issues" will also contribute to the future developments in AI (Artificial Intelligence), IA (Intelligence Augmentation), Cognitive Informatics and Cognitive Computing. Anyway, from the position of UTI, doubts have to be raised whether the new scope and agenda will further these developments or rather restrict them as far as emergence in natural intelligence is concerned.

One of the important advancements in understanding of intelligence, knowledge generation and modeling is the development of generative multi-agent models. Generative models are generalizations of cellular automata to encompass agents with different individual characteristics and types of interactions, asynchronously communicating in a general topology. Those kinds of models, (which Wolfram [2008] rightly characterized as "new kind of science") have developmental properties very useful in modeling of life phenomena. As living systems exhibit self-similar network structures from the molecular level to the level of ecology, agent modeling is the most general framework for such systems. Interesting to notice is the difference between the structural description and the dynamic description as in (multi)agent models. Even very simple structures in a course of temporal development through interactions can develop surprisingly complex patterns, and even lead computationally to randomness. [Zenil 2011] Among important insights learned from generative models and simulations in general are scale-independent network phenomena in living systems, directly connected to information communication among network nodes.

10. *Turing's problem: Can natural intelligence be fully and satisfactorily implemented non-biologically?*

The answer to this question depends on what is meant by "natural intelligence" and "fully and satisfactorily". If we consider a dolphin as possessing natural intelligence, which features shall we be able to reproduce in order to claim that dolphin intelligence have been implemented fully and satisfactorily? The development of AI seems to suggest that we will quite soon be able to reproduce the intelligent behavior of some simple living organisms. Projects like Blue Brain http://bluebrain.epfl.ch [Markram 2006] are designed specifically to simulate natural intelligence, by reverse engineering mammalian brain, first in a rat and then in a human. (This also relates to the previous question about Dennett's reengineering problem.) The biologically accurate model of the cortex, the "grey matter" of the brain that first appeared in mammals during evolution, responsible for mental capacities such as thinking, anticipation etc., has a fundamentally simple repetitive structure of neocortical column found in all mammals. The difference between rat brain and human brain is supposed to be basically just in the volume of cortex. The Blue Brain simulation re-creates this fundamental microcircuit of the neocortical column "down to the level of biologically accurate individual neurons". In 2007 the Blue Brain project announced plans to model the entire human brain within the next 10 years. From the claim that the difference in the intelligence in mammalians is proportional to the volume of the cortex, one can conclude that continued increasing of the cortex of a simulated brain will result in increasing intelligence.

There is another approach, taken by Boahen at Stanford and Meier at Heidelberg, in the FACETS project (Fast Analog Computing with

Emergent Transient States), which instead of simulating, emulates neurons, building “a brain on a silicon chip” in the form of hardware.

However, Wang [2007] would not agree with those optimistic expectations concerning non-biological intelligence, and he presents a theorem (without proof) stating:

“The law of compatible intelligent capability states that artificial intelligence (AI) is always a subset of the natural intelligence (NI), that is: AI ▯ NI”

Taking the basic assumptions of complexity in the perspective of UTI seriously (Hofkirchner 2002), Wang’s theorem would be supported: natural intelligence crucially relies on emergent information, on processes that show emergence which, according to UTI, in principle cannot be incorporated in artificial intelligence.

However, one can wonder what will happen with natural intelligence augmented by increasingly advanced AI or in general with extended mind [Clark and Chalmers 1998]. Cognitive computing devices can exceed specific human cognitive capabilities (such as logical problem solving, pattern-recognition, search, and memory). Already now there are complex software systems which exceed any single human’s comprehension, and which augment our cognition by performing cognitive tasks for us.

It is evident that not all researchers would agree on the claim that human intelligence is the limit, and indeed from the perspective of Info-computationalism, there is no fundamental reason not to exceed human level intelligence by use of cognitive machines. It will be interesting to follow the development of mentioned simulation/emulation projects aiming at (at least) human level AI.

11. The MIB (mind-information-body) problem: Can an informational approach solve the Mind-Body problem?

Within the info-computational framework ICON, [Dodig Crnkovic 2006, 2009, 2010] the mind/body problem is solved in a simple way. Mind is a *process*, information processing, and body is a physical structure (information, according to Informational Structural Realism). Mind is *a process of natural computation* that results from dynamical re-configuration/re-structuring of the information in the brain, au fait with the rest of the body which connects it with the physical world. The structure and the process are inseparably interwoven by physical laws.

Cognitive Informatics postulates two different essences: matter-energy and information: *"The Information-Matter-Energy-Intelligence (IME-I) model states that the natural world (NW) which forms the context of human and machine intelligence is a dual: one facet of it is the physical world (PW), and the other is the abstract world (AW), where intelligence (I) plays a central role in the transformation between information (I), matter (M), and energy (E)."* [2009 Yingxu Wang On Abstract Intelligence]

The above is the classical mind-body dualism but without mystical problem of connecting the physical with the intelligence/mind. It seems evident from AI that some rudimentary intelligence can be programmed into a physical medium, and if even higher level intelligence will be possible to implement non-biologically in the near future, is a question that will be resolved empirically.

Within info-computationalism, information and matter-energy is represented by information and computation. Computation presents implementation of physical laws on an informational structure [Dodig-Crnkovic 2006]. Instead of describing the world in terms of matter/energy (where energy stands for equivalent of matter) and information (which corresponds to a structuralist view of the world as consisting of stuff that changes patterns), the info-computationalist approach, using only information and computation, makes the distinction between structure (information) and a process (computation). Both formalisms can be useful, depending on the context.

In the emergentist UTI frame mind is an emergent evolutionary level of information manifestation (Hofkirchner 2002). Human mind is inextricably bound to the corresponding physical stratum (human body, human brain) brought about by evolution.

12. *The informational circle*: *If information cannot be transcended but can only be checked against further information - if it is information all the way up and all the way down - what does this tell us about our knowledge of the world?*

If we adopt Stonier's [1997] view that information is structured data, and that knowledge is structured information, we may say that information is a building block in more complex structures, but the *structure* is what makes the difference. Informational Structural Realism, ISR is developed by Floridi [2008]. The analogy may be found in the atomic or molecular structure of matter. Data would be the analogue of atoms, information of molecular or crystal structures, and knowledge the analogue of a physical object (body). If we want to understand the behavior of a living organism, we must know those structural relationships, both upwards and downwards in the complexity hierarchy.

Wang [2009, On Abstract Intelligence] argues for adding the behavior to Stoniers hierarchy:

"A key in the study of natural and artificial intelligence is the relationships between information, knowledge, and behavior. Therefore, the nature of intelligence is an ability to know and to do, possessed by both human brains and man-made systems. In this view, the major objectives of cognitive, software, and intelligence sciences are to answer:

- *How the three forms of cognitive entities, i.e., information, knowledge, and behavior, are transformed in the brain or a system?*
- *What is the driving force to enable these transmissions? "*

The transformation from information (in the broader sense as used in our context) of one kind, level, or quality to a higher information kind, level, or quality cannot be sought in a mechanistic process, since in a mechanistic process nothing new can emerge as the result is fully derivable from, and thus reducible to, the initial conditions and the mechanism in operation. Emergent information would point to self-organization as driving force. Humans do not only produce mechanistic systems as Turing-machine computers, but also build self-organizing systems as any kind of social systems.

The "information cannot be transcended …"- situation reminds of pre-Socratic natural philosophy in which only one basic cosmological principle, quintessential substance, was sought after, with prominent representatives like Anaximander who advocated apeiron as the beginning or ultimate reality from which everything existent can be derived, and the atomist school who postulated atoms as indivisible basic elements of matter.

The philosophical study of the nature of information and its relationships to intelligence leads directly to biology, (with results from among others molecular biology, developmental biology, computational biology, bioinformatics, neurobiology, ethology, evolutionary biology, biotechnology, biochemistry and biophysics, genetics, genomics, structural biology, systems biology) and other life sciences such as cognitive and computational neurosciences, ecology, neuroinformatics and similar research providing new insights from the study of living things into processes of cognition and intelligence. This process of philosophical meta-analysis must be informed by results from current research and accurately updated – the progress of life sciences at the moment is such that no single human can have complete insight into any broader field but his/her narrow field of specialization, which makes transdisciplinary collaboration increasingly important.

That information is always audited by information only is supported by the interminable cascade of building one metalevel after the other, viewed from the angle of "emergent information". Here information is the self-organized relating of a system to another event or entity and every system that organizes itself is free to position itself vis-à-vis its environment, to establish a new level and thus to add another metalevel to whatever level there exists so far. An idea like this need not to end up in radical constructivism, though. The system-made construction of a metalevel is always bound to the activity of a situated, embodied real-world system that engages with its environment and is capable of renewing its engagement according to the feedback it is exposed to from the environment.

13. *The Information Continuum Conjecture: Does knowledge encapsulate truth because it encapsulates semantic information? Should epistemology be based on a theory of information?*

If information is meant as strongly semantic information [Floridi] then the answer should be yes, as the knowledge properly constructed from strongly semantic information, should encapsulate truth. However, concept of truth may not exist when information is used in a broad context, in which reality is an informational structure [Vedral 2010].

Even in the case of "information in the wild" (e.g. biological information for which truth is not well defined) it is good to base epistemology on a theory of information, as already pointed out by Adriaans, so as to get phenomenologically informed, naturalized epistemology.

Chaitin [Chaitin 2007] argues for Epistemology as Information Theory.

Epistemology as a part of philosophy deals with human cognition on the highest level of abstraction. On the other hand, human cognition seems to be a special case of cognition that shows evolutionary stages, it is a late product of biotic evolution on earth. From a theoretical view of information in the broad sense (among others the UTI, Cybersemiotics and the ICON) cognition can be seen as a manifestation of information, and cognitive processes in human and prehuman systems as information (generation) processes. Philosophy of Information deals with information on the highest level of abstraction. Thus it should include evolutionary thinking and it is obvious that, given that assumption, there is a continuum and epistemology can be based upon the Philosophy of Information (in analogy to looking upon cognition as information process) as was initiated in Evolutionary Epistemology by Erhard Oeser 1976 and in the work of Maturana and Varela [Maturana 1970].

14. The semantic view of science: Is science reducible to information modeling?

Information modeling is at the very heart of every empirical science. Much, of course, depends on how we understand modeling. Theoretical physics, for example, uses the results of empirical models to build a further layer of theory (with additional complexity) upon those already existing, originating in data interpretation or object-level information modeling. New scientific knowledge is obtained not only from empirical data but also from existing theories. One can also view all theoretical work as a kind of modeling, too. In that case the answer would be yes, scientific knowledge is a result of information modeling even though many scientific practices do not have character of modeling – e.g. observations and measurements are fundamental interactions of intelligent agents with the environment, so they per se are not modeling. At this stage we are only in the beginning of the development of automated discovery, automated knowledge minig, automated theorem proving, and similar techniques based on the idea that science might be reducible to information modeling.

As already mentioned, in order to be able to provide relevant discourse, Philosophy of Information must be informed by life sciences as well as material sciences. Discussing Informational Structural Realism leads to the discussion of different levels of organization of the physical world – from material systems like elementary particles, atoms, molecules, planets, planetary systems, galaxies and universe[s] to living systems like biomolecules, cells, organisms, ecosystems, to human societies which are the result of the natural process of self-organization, present at different spatial and temporal scales.

Exactly that connection to the up to date research is offered in the book *Information and computation* [Dodig Crnkovic and Burgin 2011] which examines questions of knowledge [Brier], information dynamics [Burgin], mathematics as biological process (Chaitin), measurement and irreversibility (Collier), the computational content of supervenience (Cooper), mechanicist vs. info-computational world systems (Dodig-Crnkovic and Mueller), computing and self-organization (Hofkirchner), information and computation in physics as explanation of cognitive paradigms (Kreinovich, Araiza), bodies informed and transformed (B J

MacLennan), an evolutionary approach to computation, information, meaning and representation (Menant), interior grounding, reflection, and self-consciousness (Minsky), biological computing (Riofrio), super-recursive features of natural evolvability (Roglic), a modeling view of computing (Shagrir), information, for an organism or intelligent machine (Sloman), inconsistent information as a natural phenomenon (de Vey Mestdagh and Hoepman), and the algorithmic nature of the world (Zenil, Delahaye).

In analogy with the discussion of *The Information Continuum Conjecture*, it can be concluded that science is an outcome of human cognition and philosophy of science is a branch of epistemology, which entails that philosophy of science can be based upon a Philosophy of Information.

IV) **Informational Universe/Nature**

15. *Wiener's problem: Is information an independent ontological category, different from the physical/material and the mental?*

This is a question about metaphysics, and the Philosophy of Information builds on metaphysical naturalism. In order to put this view into context, it is instructive to look at the critique of present day metaphysics in the book *Everything Must Go: Metaphysics Naturalized* by Ladyman, Ross, Spurrett, and Collier, [2007] who propose a general "philosophy of nature" based on "ontic structural realism". The universe is "nothing but processes in structural patterns all the way down" (p. 228) "From the metaphysical point of view, what exist are just real patterns" (p. 121). Understanding patterns as information, one may infer that information is a fundamental ontological category. The ontology is scale-relative. What we know about the universe is what we get from sciences, as "special sciences track real patterns" (p. 242). "Our realism consists in our claim that successful scientific practice warrants networks of mappings as identified above between the formal and the material" (p. 121). This points back to the previous question about the information modeling in science. The authors provide convincing critique against traditional analytic metaphysicians who are "still talking as if the world is individual items in causal relations, rather than processes in structural patterns all the way down." The book defines verification in terms of information transfer, [p. 307-10] and adopts Salmon's process theory of causality in form of "information carrying". Even though the focus of the book is to argue for naturalized metaphysics, mainly through philosophy of physics, it is compatible with the metaphysical claims of Philosophy of Information.

Information may be conceived of as the most fundamental physical structure, [Floridi Informational Structural Realism, 2008]. It is in permanent flow, in a process of transformation, as known from physics.[2]

Information is to replace matter/energy as the primary constitutive principle of the universe, as [von Baeyer, 2003] suggests. It will provide a new basic unifying framework for describing and predicting reality in the twenty-first century. In the similar vein, Wang postulates a dual-aspect reality with matter-energy and information as its basic principles.

"Information is recognized as the third essence of the natural world supplementing to matter and energy (Wang, 2003b), because the primary function of the human brain is information processing. " [Wang 2007]

Structures are outcomes and mediums of processes. If these processes are processes of self-organization in which systems relate to events or entities in the environment, the emerging relations are structures that are essentially informational. The "emergent information" view (UTI) is in that respect "emergentist monism" as Peacocke names it [2010]; applied to information it means information is something that emerges from matter and energy. If it emerges, then matter and energy provide the necessary condition for information to come about but not a sufficient condition. That is, without matter or energy no information. In that sense, the emergentist information concept is materialistic. But it is neither materialistic in the mechanicist, reductionistic sense nor idealistic.
At a fundamental level, information can be said to characterize the world itself, for it is through information we gain all our knowledge - and yet we are only beginning to understand its meaning. [Van Benthem 2005] Among the unifying strategies there are statistical models presented in Adriaans [2010].

In the ICON dual-aspect theory of the physical universe [Dodig-Crnkovic, 2006], one sees information as a structure of the material world, while computation is its time-dependent evolution. Through biological evolution, self-organization by natural computation leads to increasingly more powerful cognitive agents. Life is cognition according

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[2] A forthcoming issue of the journal Information is dedicated to matter/energy and information http://www.mdpi.com/journal/information/special_issues/matter and will try to elucidate those fundamental relationships.

to Maturana and Varela [1980] and it produces intelligence, based on information processing.

Physicists Zeilinger [2005] and Vedral [2010] suggest seeing reality and information as one. Researchers such as Chiribella (Perimeter Institute for Theoretical Physics) are working on the development of the mathematics of quantum theory completely reconstructed from a set of principles about information processing. “*The key principle in our reconstruction of quantum theory is the "purification principle", stating that every mixed state of a system A can be obtained as the marginal state of some pure state of a joint system AB. In other words, the principle requires that the ignorance about a part be always compatible with the maximal knowledge of a whole.“*
http://www.comlab.ox.ac.uk/seminars/532.html

Even biology adds to this information-based view of the Universe/Nature: *“When reconceptualized in equivalent terms of self-organizing adaptive networks of energy/matter/information exchanges, complex systems of different scales appear to exhibit universal scale-invariant patterns in their organization and dynamics, suggesting the self-similarity of spatiotemporal scales and fractal organization of the living matter continuum.”* [*Kurakin* 2007 and 2009]

From the fields of physics and biology new insights essential for the Informational Universe/Nature may be expected in the years to come.

16. The problem of localization: Could information be neither here (intelligence) nor there (natural world) but on the threshold, as a special relation or interface between the world and its intelligent inhabitants (constructionism)?

In the dual-aspect theory of information/computation there is no Cartesian divide between body and mind. [Dodig Crnkovic 2005 - 2011] The Naturalized epistemology approach [Dodig-Crnkovic, Entropy], conceptualizes information as both here (intelligence) and there (world) and on the threshold, as information constitutes the basic existence. Its structural changes are the results of computational processes. We have a long way to go in learning how exactly those computational processes are to be understood and simulated on different levels of organization of informational structures, but the first step is to establish the basic conceptual framework.

On the other hand, in the Hofkirchner’s UTI view (2010), information is neither outside in the first (natural) world nor in a Platonist third world waiting for being collected, detected and received by intelligent beings nor is it something constructed by intelligent beings and residing in their second world only. In UTI, information is overarching and comprising complex material systems and their environment, connecting them by the establishment of relations between them that become manifest in a change of the structure, or the state, or the behavior of the systems. As such, information is part of the natural world but it is bound, exclusively, to the existence and activity of self-organizing systems and cannot exist without, or external to, that. Information as objective relation between a "subjective" system and its environment can become itself a trigger for another information process in which another "subjective" system relates itself to that very information via another "subjective" change in its own structure, state, or behavior. The term "subjective" is used here to characterize the spontaneity of complex systems when self-organizing and is meant to come in degrees according to evolutionary stages complex systems represent.

17. The "It from Bit" hypothesis: Is the universe essentially made of informational stuff, with natural processes, including causation, as special cases of information dynamics?

The development in this direction can be seen in Floridi [ISR 2008] who argues for Informational Structural Realism. The fundamental claim of info-computationalism [Dodig-Crnkovic 2006] which builds on ISR, is that the universe is essentially made of informational stuff, and computation which may be seen as implementing physical laws, is what governs information dynamics.

In his "Universe from Bit" Davies [Davies and Gregersen, 2010, pp. 65-91] argues for a shift in the sequence of mathematics, physics and information: "The traditional relationship between mathematics, physics, and information may be expressed symbolically as follows: Mathematics → Physics → Information". "The variant I wish to explore here is to place *information* at the base of the explanatory scheme, thus: Information → Laws of Physics → Matter" (p. 75). The rationale is that "the laws of physics *are* informational statements" (p. 75). Though this might seem an ontological flaw, Davies can state at the same time that "the laws of physics are inherent in and emergent with the universe, not transcendent of it" (p. 83) because he postulates "a self-consistent loop: the laws of physics determine what can be computed, which in turn determines the informational basis of those same laws of physics" (p. 87).

The thesis that the laws of physics evolve because of, and together with, self-organizational capabilities of the systems inhabiting the universe is in compliance with the view that the laws of physics are not a given to the universe but completely of this world – a view that is shared by the emergentist variety of information concepts (UTI) which would still stick to the opposite of the saying “It from Bit”: “Bit from It.

V) **Values/Ethics**

18. Are computing ethics issues unique or are they simply moral issues that happen to involve ICT? What kind of ethics is CE? What is the contribution of CE to the ethical discourse?

It is interesting to follow the evolution of this question which firstly concerned the existing Computer Ethics, then Computing Ethics and finally Information Ethics, defining increasingly more abstract subject. Floridi’s focus, initially on computing [Floridi 1999] shifted gradually towards information as the most abstract and fundamental principle and he developed Information Ethics (IE) as a part of his Philosophy of Information (PI). In what follows we comment on the developments within *Information Ethics*, leaving Computer Ethics/Computing Ethics as a historical origin from which the whole programme started.

Froelich [2004] introduces the history of Information Ethics by the claim: *“Information ethics has grown over the years as a discipline in library and information science, but the field or the phrase has evolved and been embraced by many other disciplines.”* Froelich mentions contributions by Capurro (1988), who in 1999 founded the International Center for Information Ethics, Severson (1997), Johnson (1985), Sullivan (1996), Spinello (2003) and number of others.

Starting from paper on Information Ethics [Floridi 1999a], Floridi’s research in IE [Floridi 1999a, 2002a, 2008a] has attracted considerable interest in the research community and it was presented and reviewed with several occasions in special issues of journals.

Two issues of APA's Newsletter have discussed Floridi’s work. In the fall of 2007, Floridi published an article in the newsletter titled *Understanding Information Ethics*. In the next issue of the newsletter [Boltuc 2008a] a number of commentaries were published by prominent ethicists as a response to Floridi’s article addressing topics such as IE as macroethics (Vaccaro), re-ontological revolution (Sullins), discursive explorations in IE (Buchanan), and problems of infosphere (Chopra). The discussion continues in the next issue [Boltuc P. 2008b] of the APA newsletter, with articles on metaphysical foundation for IE (Bynum), good and evil in IE (Barker), moral status of informational objects (Howlett Spence). The debate concludes by Floridi's *Understanding Information Ethics: Replies to Comments*, published in 2009. [Floridi 2009a]

A special issue of the journal *Ethics and Information Technology* in 2008, edited by Charles Ess [Ess, 2008] titled *''Luciano Floridi's Philosophy of Information and Information Ethics: Critical Reflections and the State of the Art''*, witness about the vitality of the PI and IE research programme. Dodig Crnkovic [2011] addresses several critical views from [Ess 2008] caused by misunderstandings of the role which IE plays in relationship to other ethical theories. It is argued that IE is a fundamental level approach which, as an instrument of enquiry, can be used for specific purposes, and not as a replacement for all existing tools of ethical analysis. Understanding of the proper application is essential, for otherwise it would be like using a microscope to observe astronomical objects and concluding that it does not work.

Floridi's IE focuses on the fundamentally informational character of reality [Floridi 2008a] and our interactions with it. According to Floridi, ICTs create our new informational habitat which is an abstract equivalent of an eco-system. As moral judgments vitally depend on the information about the present state and what is understood to be a desirable state of affairs, the macro-ethical behavior of networks of agents depends on mechanisms of information processing and communication. Information streams in the Infosphere can both enrich and pollute the informational environment for an agent. Those informational processes are essential in the analysis of the behavior of networks of agents, biological and artificial.

Classical ethics approaches typically look at individual (e.g. Virtue Ethics) or a group behavior (e.g. the Ethics of Rights) while IE provides a framework for an agent-based approach. It is important to notice that Floridi's Philosophy of Information with Information Ethics is a research programme and not a single theory. As a macro-ethics, applicable to networks of communicating agents and at the same time giving a fundamental-level view of information patterns and processes IE can help identify general mechanisms and understand their workings. The insight into the underlying informational machinery helps to improve our analysis of ICT-supported systems. It is now possible to study the effects of different sorts of information communication, and their influence on informational networks, including the role of misinformation, disinformation, censorship (lack of information) and similar. There are many parallels between IE and environmental ethics, of which IE is a generalization, where the Infosphere may be understood as our new cognitive environment. However, there is an important sense in which they differ. Environmental ethics is placed on the same “macroscopic” and everyday-life level of description, while IE is on a more abstract level of information structures and processes.

IE is likely to continue developing as one of the tools of investigation which will help improve understanding of ethical aspects of life in an increasingly densely populated infosphere. We are far from being able to reconstruct/generate/simulate the structure and behavior of an intelligent agent or a network of agents starting from proto-information as the stuff of the universe.

IE is not a machine for production of the ultimate ethical advice, but a promising analytical instrument especially suitable for ethical analysis of techno-social systems with mixture of humans and artificial intelligent agents. With the development of agent models we may expect numerable new applications of IE. Floridi’s comments [2008a] on the articles in [Ess 2008] can be summarized as: “There are, however, ‘‘correct accounts’’ that may complement and reinforce each other, like stones in an arch.“ [Floridi 2008]

IE is far from a closed chapter in the history of ethics. Contrariwise, it is of great interest for many researchers today, and its development can be expected to contribute elucidation of number of central issues, particularly related to the systems of biological and artificial agents.

IE is manifestly a research field in its own right. It is not only an extension of classical ethical issues to the realm of the infosphere today enhanced by ICTs. The contents of the extension cannot be reduced to traditional ethics, that is, it is not possible to deduce findings in or for IE from the body of traditional ethics plus the premises that represent the conditions of the existence of ICTs.

ICTs raised new issues in which philosophy has to reconcile the particular with the universal. However, it is in contest whether or not artificial devices can be regarded as informational agents that are patients [see Capurro 2009]. Capurro, together with number of other ethicists, argues that ICTs receive their meaning by the very act of being instrumental in human self-organization. And this meaning is related to the purpose for which ICTs are made and to the purpose for which they are used and to the good or evil that is associated with their non-intended consequences in the social, biotic, physical subsystems. Without their embeddedness in human self-organization, in the suprasystem of societies, they would be meaningless. And therefore it is of utmost importance to consciously and cautiously integrate ICTs in the bigger picture. However, we need not to postulate intrinsic values of all the entities to be morally guided to respect them (Hofkirchner 2010, p. 188). In Hofkirchner's UTI framework self-organizing systems, including humans, are both agents and patients in varying degrees and are evaluated in informational settings by each other.

In sum, Information Ethics has undoubtedly established itself as a unique research field. In the future we expect IE to elaborate relationships with other ethical theories, and demonstrate applications in different contexts, especially when it comes to the blend of natural and artificial agents in techno-social informational environments far from traditional classical ethical scenarios.

Conclusions

"In retrospect, all revolutions seem inevitable. Beforehand, all revolutions seem impossible." McFaul M., US National Security Council, NY Times June 21, 2009.

In hindsight we can conclude that Floridi's programme identified information-level approaches as the most important nuclei of crystallization of knowledge in a variety of research fields, from natural to human sciences. Philosophy of Information can be seen as encompassing both Natural and Human Philosophy (Bacon's distinction), based on the results of the advances in the information studies and the development of computing technologies and theories. It thus provides an overarching view, bridging the traditional division between the knowledge of non-living and living world. [Dodig Crnkovic Entropy] Among central problems of Floridi's program are the informational universe, intelligence/cognition and nature of knowledge in relation to information.

Successively, in the past decade, the information processing paradigm of cognition has gained dominance because of its ability to provide suitable framework for the interdisciplinary communication and learning about intelligent mind and agency. Despite of all impressive progress made in recent years, human mind is still to a high extent poorly understood. For the study of the nature of information it is essential to understand information processes and structures in the brain and nervous system. As "nothing makes sense in biology except in the light of evolution" [Dobzhansky 1973 p. 449], the problem of informational reconstruction of human mind is also necessarily done "in the light of evolution".

In years to come we expect to see answers to Floridi's questions about intelligence/cognition and information semantics to emerge from both empirical and theoretical work in neuroscience, cognitive informatics, natural computing/ organic computing, generative modeling, bioinformatics, intelligent systems and robotics, and more.

The development of Philosophy of Information can be seen as proceeding simultaneously at two levels, through the:

1. externally driven philosophical reflection on the advances of the underlying research fields providing the best current knowledge of the informational nature of the world

2. internal restructuring of the PI itself as a philosophical discipline with ability to adapt to the rapidly changing world of its subject matter.

What can we expect from the Philosophy of Information in the future?

Adriaans [2010] adds to the list of remaining open problems of PI: the nature of various probability distributions that dominate logical, physical, biological end cultural domains; the interaction between information and computation; the approximation of various compression measures and the study of cognition and learning as data compression.

Van Benthem in the Handbook of Philosophy of Information proposes the following additions to the list: visual and other information carriers beyond language; information and context as well as information, interaction and games.

We would suggest including the Complexity as one of the focus research areas where information is the basic concept and where essential improvement of our current understanding of systemic behavior of information can be expected. Improved understanding of information structures and dynamics in networks is important for broad range of phenomena from networks of neurons to social phenomena.

Significant insight from biology [Kurakov 2007] that

"*diverse complex adaptive systems, such as proteins, cells, organisms, organizations, societies and ecosystems, all together constitute one developing, multiscale continuum-economy composed of interacting and interdependent adaptive organizational forms that co-exist and co-evolve at different spatiotemporal scales, forming a nested set of interdependent organizational hierarchies."*

presents itself as natural cohesive mechanism between different levels of abstraction and should be taken into account.

As a part of the study of the mutual relationship of information and computation, it is vital to look at the agency/behavior/computational aspects of information. This is a domain of *pragmatics of information* which together with *syntactic aspects of information* deserves special focus in the future development of PI.

Interesting to notice is the phenomenon Philosophy of Information has in common with several current research programmes: the dynamical equilibrating of the building on a moving ground. It is building a framework based on the best current knowledge from several fundamental disciplines all of which are simultaneously undergoing paradigm shifts – from logics (changing ideas of truth, formal system, proof, identity, contradiction, temporal and dynamic logic), computing (generalized idea of computing, natural computing, organic computing), cognitive science (new insights into mechanisms of human mind and its relationships to body and environment), neuroscience (basic level understanding of neural information processing), biology/bioinformatics (computational models of basic biological processes), physics (info-computational foundations of physics), sociology (generative models of agent networks) and semiotics (meaning production in succession of levels of organization in living agents) to the changing understanding of what indeed science is and what it should be in the future.

It should be pointed out that Philosophy of Information is a vast field and in this paper we have been able only to briefly sketch some of the developments during the past ten years. Our work can only be a very modest contribution, to paraphrase Abramsky: not least for the reason that the research field we are attempting to overview does not exist yet in a fully realized form. [Abramsky 2008]

Given the context of major paradigm shifts we are experiencing, Philosophy of Information should not be envisaged as an automaton producing timeless correct statements about the world, built on the ground of basic theories in the process of transition. PI can instead provide a valuable cognitive tool for understanding of informational phenomena on a more general level which we can consult instead of depending on notoriously unreliable collective intuitions. As an integrative framework PI is expected even in the future to provide dynamic epistemic support for number of research communities connected by the fundamental idea of information.

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