

Situating Logic and Information in Information Science

Murat Karamuftuoglu

Department of Communication and Design, and Department of Computer Engineering, Bilkent University, Bilkent, Ankara 06800, Turkey. E-mail: hmk@bilkent.edu.tr

Information Science (IS) is commonly said to study collection, classification, storage, retrieval, and use of information. However, there is no consensus on what information is. This article examines some of the formal models of information and informational processes, namely, Situation Theory and Shannon's Information Theory, in terms of their suitability for providing a useful framework for studying information in IS. It is argued that formal models of information are concerned with mainly ontological aspects of information, whereas IS, because of its evaluative role with respect to semantic content, needs an epistemological conception of information. It is argued from this perspective that concepts of epistemological/aesthetic/ethical information are plausible, and that information science needs to rise to the challenge of studying many different conceptions of information embedded in different contexts. This goal requires exploration of a wide variety of tools from philosophy and logic.

Introduction

The purpose of this article is to investigate the relevance of logic and mathematical conceptions of information to the discipline of Information Science (IS). One mathematical framework that aims to provide a calculus of information, more accurately "information flow," is the Situation Theory (ST) developed by Barwise & Seligman (1997), Barwise & Perry (1983), Devlin (1991), and others. ST is related to a number of other semantic theories of information (such as Drestke, 1981; Bar-Hillel & Carnap, 1953), and it has been suggested that it could provide a basis for information retrieval (IR) (Rijsbergen & Lalmas, 1996). ST is based loosely on the Mathematical Theory of Communication (MTC) of Shannon & Weaver (1949), popularly known as "Information Theory." The relevance or otherwise of MTC to IS, and more generally to semantic conceptions of information, is a much debated topic (see Machlup & Mansfield, 1983; Floridi, 2005). The present article aims to contribute to this discussion by showing the importance of epistemological orientation in developing a conception of information for IS.

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In the following I analyze and criticize the concept of information in ST, and more generally in formal logic, and demonstrate that conceptions of information that neglect or do not explicitly acknowledge the epistemological basis of informational acts are not adequate for the purposes of information science. I will argue that, notwithstanding the limitations of the conceptions of information in logic, formal approaches to information are useful for deepening the understanding of information in IS and IR. For this reason I will argue for an expanded scope for IS, which includes the study of formal logic and the "philosophy of information" (see Floridi, 2005, 2003).

The Scope

The debate about whether "information" or "document" is the primary object of study in information science is a complex and multifarious one (see, for example, Ørom, 2007). A note on the scope of the present article is therefore in order. Among the many points of contention is the claim that document is a better unit of analysis than information for the purposes of IS. For instance, Spang-Hansen (2001) writes that:

Information about some physical property of a material is actually incomplete without information about the precision of the data and about the conditions under which these data were obtained. Moreover, various investigations of a property have often led to different results that cannot be compared and evaluated apart from information about their background. An empirical fact has always a history and a perhaps not too certain future. This history and future can be known only through information from particular documents, i.e. by document retrieval.

His point seems to be that the context and historical background of an event or an entity is lost when information is abstracted from it, as in the case of an idea or a proposition extracted from the document that contains or expresses it. Hence, the argument is that document is a more appropriate unit of analysis than information for the purposes of information science. However, the fact is that creation of a document implies abstraction in the first place. This fact is underlined in Buckland's discussion of Suzanne Briet's, one of the pioneers

of documentation, conception of document (Buckland, 1997, p. 806):

There is discussion of an antelope. An antelope running wild on the plains of Africa should not be considered a document, she [Briet] rules. But if it were to be captured, taken to a zoo and made an object of study, it has been made into a document. It has become physical evidence being used by those who study it. Not only that, but scholarly articles written about the antelope are secondary documents, since the antelope itself is the primary document.

I agree with the view that production of information (as well as document) implies abstraction from context, and thus loss of specificity. Previously (Karamuftuoglu, 2006) I argued for a conceptualization of information in terms of the amount of decontextualization involved in its production. However, the aim of the present article is to develop, first, a concept of information relevant to IS based on epistemology, and second, demonstrate that it is, although distinct from, compatible with formal logical conceptions of information. The discussion of whether information or document is or should be the primary unit of analysis in information science is outside the scope of the present article. My view is that both concepts have a distinct but significant role to play in IS.

Some researchers cast doubt on the relevance of epistemology to IS. For instance, Furner (2004) argues that:

Commonly, the everyday conception of knowledge (as the content of mental states) is contrasted with a philosophical conception of knowledge (typically, as justified true belief). . . . Somewhat oddly, given the nature of the conception of knowledge that is typically adopted in such accounts, a tendency has been for authors to go on to use the results of this kind of analysis to locate IS with respect to epistemology. A more productive approach might instead be to relate work in IS to that in philosophy of language. . . .

. . . [P]hilosophers of language have modeled the phenomena fundamental to human communication in ways that do not require us to commit to a separate concept of “information.” Indeed, we can conclude that such a concept is unnecessary for IS. Once the concepts of interest have been labeled with conventional names such as “data,” “meaning,” “communication,” “relevance,” etc., nothing is left (so it may be argued) to which to apply the term “information.”

Such an approach, I believe, overlooks the potentially fruitful relationship between IS and cognate fields such as the philosophy of information and formal logic. As I will discuss in detail below, the philosophy of information and formal logic are concerned mainly with the description of the state of affairs in the world, i.e., ontology. Information is, therefore, framed in these disciplines from that particular perspective. On the other hand, as I will elaborate in the rest of the article, information science is concerned mainly with human situations that involve negotiation and evaluation of rules and meta-rules that concern knowledge and value standards. Such issues are studied by, among others, epistemology. Information in information science thus needs to be framed from

an epistemological viewpoint. Although epistemological and ontological concerns are distinct, they are also complementary. Furthermore, as discussed in detail in the latter parts of the article, both formal and informal logics are useful in such tasks as subject analysis and classification. It is, therefore, important to develop a concept of information relevant to the core activities in IS, and also congruent with the conceptions of information in cognate disciplines, specifically, logic and the philosophy of information. It is also worth noting that epistemological research is not limited, as it seems to be suggested in the above paragraph by Furner, to the analytical tradition in philosophy. There are other approaches, such as social epistemology, “. . . which reject or ignore such classical concerns of epistemology as truth, justification, and rationality. . . .” (Goldman, 2006). The present article is closer in its orientation to social approaches to epistemology than classical or analytical approaches.

Whether IS deals directly with information or *informs* by means of documents there seems to be no ground for excluding the study of information from an IS perspective. The main goal of the present article is to situate information in the context of IS and in relation to cognate disciplines that study it. The remark below by Alfino captures the essential goal of the present article (cited in Herold, 2001):

To think about information rigorously you must read from several disciplines, since information is not the specific object of study of any one field. The *division* in thinking about information is between more or less technical accounts which suppose that information can be studied as a distinct object in relative isolation from culture and scholars who feel that we can only talk about information in relation to a ‘cultural semiotic.’ [italics added]

The present article aims to bridge that division by elaborating a concept of information congenial with the worlds of both logic and mathematics, and sociology and semiotics.

The Meaning of Information

Information is an ambiguous term. Capurro & Hjørland (2003) state that: “Almost every scientific discipline today uses the concept of information within its own context and with regard to specific phenomena.” (p. 356). “There are many concepts of information, and they are embedded in more or less explicit theoretical structures.” (p. 396). These statements express, in my view, an important aspect of the concept of information, and constitute one of the cornerstones of the analysis of the concept in this article.

Informational acts are acts of cognition. Every cognitive act, that is, process of knowing, involves a relation between an object and a subject. Information is a product of such an act. A subject who is engaged in an informational act, that is, an act of cognition, manifests two orientations—toward the object of cognition, i.e., ontological, and toward the process of knowing, i.e., epistemological.¹ Every cognitive act is, therefore, an expression of ontological and epistemological interests. Analysis of the concept of information, thus, has to be conducted on two dimensions: ontological

and epistemological. I will illustrate and defend the above premise in the pages that follow by a number of examples from different domains: computer science, information science, mathematical theory of communication, art, and instances of everyday mundane communication.

Ontological Orientation in Information: The Case of Situation Theory

Situation Theory (ST) provides a mathematical framework for modeling flow of information. It is loosely based on the Mathematical Theory of Communication (MTC) of Shannon & Weaver (1949), popularly known as “Information Theory.” Situation Theory, and Situation Semantics, which is based on it, are related to modal logic and possible world semantics (Perry, 1997, p. 669): “Situation semantics was originally conceived as an alternative to extensional model theory and possible world semantics . . . Situations are contrasted with worlds; a world determines the answer to every issue, the truth-value of every proposition. A situation corresponds to the limited parts of reality we in fact perceive, reason about, and live in.”

Situations are structured entities that consist of objects standing in certain relations (Kratzer, 2008). ST is a formal language or calculus for deriving inferences between two situations. In this sense, ST is a mathematical framework to model information, more precisely, “mathematical model of information flow” (Devlin, p. 3). I will illustrate by means of an example the flow of information in ST. Consider the following set of plausible events or situations:

I am at home and I hear the doorbell ringing. The reader would probably think that I would immediately assume that there is somebody at the door. However, my doorbell is in fact a chime, which is triggered not only when it is struck intentionally but also when there is a strong wind outside. This is why I do not immediately rush to open the door every time I hear the doorbell ringing. In fact, I normally bother to answer the door only if I know that there is no strong wind outside, i.e., when there is no physical sign perceptible from inside the house, such as the sound of the wind, or the sight from my window of the trees bent under the wind. There may be reasons other than the strong wind or someone intentionally ringing it for the doorbell to sound. I know that kids sometimes play ball outside my door and hit the chime accidentally with it, which also causes it to ring.

In the above scenario, there are three distinct events or situations that correlate with the doorbell ringing: someone at the door ringing the bell; kids hitting it accidentally; the wind blowing the chime. ST provides a formalism to model the objects and the relations between them (situations), and semiformal deductive apparatuses (or inference rules) to infer the state of affairs in one situation (doorbell is hit by a ball or struck by someone or blown by the wind) from the state of affairs in a linked² situation (perception of the doorbell ringing).

Humans, more generally, cognitive agents (animals, “intelligent” machines, etc.) comprehend the world by

classifying it in terms of objects. This process of discriminating uniformities in the world is referred to as *individuation* in ST, and the entities individuated by the agent as *individuals* or *objects* (Devlin, 1991, p. 21). Information in ST is seen as a collection of objects and relations between them in the form:

objects a_1, \dots, a_n do/do not stand in the relation P . (Devlin, p. 22).

For example, in the scenario described above we have the following basic informational item or structure, known as an *infor*:

$\langle\langle \text{ringing, doorbell; 1} \rangle\rangle^3$

which denotes that object *doorbell* stands in relation P — *ringing*. Whereas,

$\langle\langle \text{ringing, doorbell; 0} \rangle\rangle$

denotes that object *doorbell* does not stand in relation P — *ringing*.

Infons are, therefore, mathematical abstractions that convey semantic content. An infor in itself is not true or false; it acquires a truth-value in a specific situation or context. An infor becomes true if there is a situation s in which the statement expressed by the infor holds. This is denoted by:

$$s \models \sigma$$

where σ is an infor and s is a situation, which “supports” it, or makes it true.

Let σ denote the infor that the doorbell is ringing and, σ' that there is someone at the door:

$$\begin{aligned} \sigma &= \{\langle\langle \text{ringing, doorbell; 1} \rangle\rangle\}, \\ \sigma' &= \{\langle\langle \text{present, someone, door; 1} \rangle\rangle\} \end{aligned}$$

If s denotes the situation that “I hear the doorbell is ringing,” then $s \models \sigma$ and if s' denotes the situation that “there is someone at the door,” then $s' \models \sigma'$. The inference that there must be someone at the door (made by the cognitive agent who hears the doorbell) is represented by: $s \xrightarrow{c} s'$, where \xrightarrow{c} denotes that there is a “channel” which links situation s to situation s' . In other words, situation s contains information about situation s' , viz., information that there is someone at the door is inferred when the sound of the doorbell is heard.

Channels are mechanisms for modeling the links or informational connections that support information flow between situations. Rijsbergen & Lalmas (1996, pp. 391–392) give an example of a channel that models the synonymy relationship in a thesaurus:

$$\langle\langle \text{present, belief; 1} \rangle\rangle \xrightarrow{c} \langle\langle \text{present, dogma; 1} \rangle\rangle^4$$

The above statement expresses that if a document contains the term “belief” then it also (implicitly) contains the term “dogma.”

ST provides an ontology (objects, situations, channels, etc.) and a set of logical principles (inference rules) that determine the scope of deductions that can be made, and thus, the type of questions that could be asked about the state of affairs in a given situation. Insofar as we are concerned with objects and the relations between them, i.e., situations, and the formal mechanisms of making inferences about situations (I hear the doorbell ringing \rightarrow someone is probably⁵ at the door pressing the doorbell), ST provides a theory of *factual information*.⁶ I will call this type of information as *ontological information* to distinguish it from *epistemological information*. In the former case, the agent deduces (e.g., I upon hearing the sound of the ringing doorbell) certain information about the state of affairs in a certain situation (someone pressing the doorbell, or chime is being blown by the wind), that is, individuated entities and the relations between them. In the latter case, which is discussed in detail in the next section, the agent confronts a situation where the previous experiences of similar situations fail to explain the current situation, hence forces the agent to formulate new hypotheses, which requires a creative act.

As we have seen, information flow in ST is enabled by constructs named as channels and constraints.⁷ There are four main types of constraints (Seligman & Moss, 1997, p. 299):

1. Necessary Constraints, including taxonomic relations between properties like ‘moles are mammals,’ appropriateness conditions like ‘sipping involves sipping something,’ incompatibility restrictions between properties like ‘red things aren’t green,’ or even between individuals like ‘Kriesel is not Keisler,’ and mathematical constraints like ‘ $5 + 7 = 12$.’
2. Conventional Constraints, including linguistic rules, syntax, and semantics, the rules of backgammon, or the convention of driving on the right side on the road.
3. Nomic Constraints, including all laws of nature, both the commonplace—such as the law that unsupported coffee mugs fall to the floor, and that the radio works if you hit it—and the more esoteric laws about chemical valency or electromagnetism. Most notoriously, ‘smoke means fire’ expresses a nomic constraint.
4. Meta-theoretic Constraints, including all those laws that form a part of Situation Theory itself, such as the law [sic] that if $s \models \sigma$ then s is a situation and σ is an infon.

The above list appears to be haphazard (Seligman & Moss, 1997, p. 299), and the model does not tell us how to identify or choose the right constraint or channel for inference. Changing the channel amounts to changing the information flow (Lemon, 1998), thus, the channel/constraint determines what can be known about a situation. For instance, consider the use of WordNet⁸ as a channel as proposed by Rijsbergen & Lamas (1996). Information science is related to computer science through the meronym relation in WordNet, that is, computer science is a part of information science. However, according to WordNet, documentation is not related to IS. In fact, it is not even recorded as a discipline in WordNet. However, for instance, the article by Hjørland & Capurro (2003) takes a view that documentation is an important part

of, if not synonymous with, information science. The present article takes a different view on the same issue. This brief discussion illustrates that what channels model depends on the particular theoretical/epistemological position one takes. The main issue with the constraints in ST is therefore: “. . . the epistemological role of constraints, and not their ontological status. A constraint is something that allows someone with information about one situation to gain information about a possibly different situation.” (Seligman & Moss, 1997, p. 300).

On the epistemological consequences of the constraints/channels in the act of knowing ST is silent.⁹ This marks the limit of its usefulness as a basis of theory of information for IS. At this point it is worth remembering that ST is a theory of factual information (a kind of semantic information) implementing a naïve epistemology that could be termed empirical realism¹⁰ by means of channels and constraints (necessary, conventional, nomic, etc.). The other variety of semantic information is *instructional* information: “Instructional information is not about a situation, a fact, or a state of affairs w [orld] and does not model, or describe or represent w . Rather, it is meant to (help to) bring about w . For example, when the mechanic tells one over the phone to connect a charged battery to the flat battery of one’s car, the information one receives is not factual, but instructional.” (Floridi, 2005).

Instructional information is, hence, related to performative acts. Performative acts or utterances are *prescriptions*, in the sense that they bring about changes in the state of affairs in the world, such as in the case of the sentence “I name this boat Kon-Tiki.” In this sense they are opposite of descriptions, which inform us about the state of affairs in the world. Performatives/prescriptives are rule-changing acts, which bring us to see the world in a different light (Karamuftuoglu, 1997). In this sense, “. . . a prescriptive utterance cannot be derived from description. Prescriptives are ungrounded, they are ‘left hanging’ in the sense that they cannot be derived logically or necessarily from what is the case, from ontology. . . .” (Schrift, 2006, p. 69). Prescriptive/performative acts, therefore, give rise to a totally different mode of communication than deductive inferences, which informs us about the state of affairs in the world, as is the case with ST and other factual models of information. I will analyze next the concept of information from the perspective of prescriptive acts.

Epistemological Orientation in Information

In this section I will argue that the same set of events described above (sensory perception of doorbell ringing and someone pressing the doorbell, etc.) contains or may bring about *epistemological information* (as well as other types of information, such as aesthetic and ethical, see the section Other Varieties of Information: Aesthetic, Ethical, below). Consider the following extension to the set of events described earlier regarding the ringing doorbell:

I hear the doorbell chiming, but there is no wind outside.
I know the kids are at school, therefore there must be someone

at the door. I get to the door to greet the person, but there is no one in sight. I got to the door quickly, therefore it cannot be that someone rang it and walked away before I opened the door.

At this point in the above scenario I have already made a hypothesis, which I then quickly abandoned, namely, that someone rang the doorbell and ran away. Clearly, we are now dealing with a problem-solving situation, which involves making assumptions, sorting facts or objects relevant to the problem from those that are not, individuating new objects, building hypothesis, and evaluating them. This mode of reasoning is known as *abduction*. Abductive reasoning where questions such as “What is there to know,” “What facts/entities are relevant to the problem,” “How could I acquire relevant information,” etc., are asked, and answers for them searched, is categorically different from the kind of mechanical inference afforded by constraints/channels in ST. In the above case of the inexplicably ringing doorbell, the anomaly faced by the cognitive agent forces her to forsake the usual explanations formed by expectations based on repeated past experiences and/or conventions, and formulate a new hypothesis. But forming a new hypothesis usually requires critical examination of the presuppositions held regarding the foundations, valid sources, forms, and methods of knowledge acquisition, and the rules of inference, i.e., epistemological assumptions. Insofar as the agent critically examines and consequently revises the epistemological assumptions relevant to a given situation, it may be said that she acquired or the situation imparted *epistemological information*.

Acquisition of epistemological information, therefore, results in a change in the knowledge of the methods of acquiring knowledge about things in the world, and the scope and validity of such methods. In short, epistemological information changes the vantage point from which an agent comprehends the world. It concerns the theoretical positions from which one approaches the problems faced in the world. At this point, two aspects of epistemological or epistemic information need clarification. Informal approaches to epistemology (e.g., Gärdenfors, 1988; Hendricks & Symons, 2006), which is also known as *epistemic logic*, the belief/knowledge states of agents as well as the dynamics of belief/knowledge revisions are modeled. Epistemological and ontological concerns, although distinct, are closely related. However, in this article the dynamics of belief/knowledge changes is emphasized instead of the products of such changes (i.e., the resultant mental states) when epistemological information is mentioned. Furthermore, whereas the literature on epistemic logic concerns mainly an individual agent’s or a collection of such agents’ cognitive states, epistemological orientation in information as conceived in this article emphasizes the transindividual social structures, such as paradigms and metatheories in discourse domains.

To clarify this issue I will now reconsider the case of a fictitious work of information art,¹¹ which I used elsewhere

(Karamuftuoglu, 2006) to discuss the aesthetic value of an artwork as a function of its potential to inform research questions pertinent to the scientific disciplines from which the work derives its methods, concepts, or tools:

Let us assume that there is an immersive 3D interactive art installation, which represents a library where users (i.e., viewers) manipulate the books and other items on the shelves directly by hand movements without the use of a mouse. . . . It is conceivable that this installation could inspire a researcher working in the field of digital libraries to imagine alternative interface designs. Although interface design for retrieval systems is a valid problem for information scientists, arguably it is not a core research area in information science. The idea of an immersive interface whereby users interact with documents with hand movements and gestures could be a useful idea for IR researchers regardless of any particular research paradigm within which they work. . . .

Let us now imagine that the installation is such that queries of previous visitors (i.e., users) are recorded and visually represented as floating clouds in a 3D virtual library, which persist after the owners of the queries left the installation, and newcomers could see and manipulate them. We could imagine that an IR researcher, working from within a socially informed perspective, could be inspired by it and formulate the idea that collaboration between past and present users of IR systems could be possible and desirable. . . . [T]his is a work of art relevant to socially oriented paradigm(s) in IR, such as the sociocognitive view. . . .

Let us now imagine that we traveled back in time 30 years or so, when the only established paradigms [in IS] were the archetypal and cognitive. . . . Imagine that socially informed theories did not exist at that time. It is plausible, then, to argue that the same interactive art described earlier could stimulate an IR researcher working within either the archetypal or, more likely, the cognitive paradigm to challenge the basic philosophical assumptions of that particular paradigm, for example, those related to methodological individualism. (Karamuftuoglu, 2006, pp.1788–1789).

The cognitive paradigm in information science is characterized by its focus on the individual user and her mental models, knowledge-structures, etc., which is related to methodological individualism (Hjørland, 1997b). It holds certain epistemological assumptions regarding the nature of knowledge and the right way to do research in IS. The end result of the interaction between the researcher and the fictitious artwork in the above-described scenario is, therefore, a shift in the epistemological assumptions of the researcher from those grounded in methodological individualism to what could be termed social-constructivism, which focuses on communities, institutional practices, division of labor in society, and holds a different set of assumptions about the nature of knowledge and knowing. To the extent that one can still use the transmissional metaphor of information it is possible in the above scenario to speak of flow of epistemological information from the source (the art installation) to the target (the IR researcher), or more appropriately, acquisition of epistemological information by the cognitive agent from the given situation.

Varieties of Information

In the preceding pages infons and situations are interpreted as abstractions that convey semantic relations. There is a danger in taking infons not as mere mathematical entities but real “things” in the world that are transmitted between situations. This is known as reification in philosophy. Reification is a process where abstract entities or concepts are treated as concrete “things” (Kemerling, 2002). Rijsbergen & Lalmas (1996, pp. 388–389) note, “In Situation theory the concept of *situation* is primordial. A situation is where information resides. . . . Situation Theory is explicit about the ontology of situations. It treats them as genuine entities in their own right, not merely as formal devices as in semantic-model approaches.” Devlin (1991, p. 46) states that: “A mathematical theory of information needs some specific notion of an ‘informational object’ or an ‘item of information’ to work with. It may or may not be the case that cognitive agents actually function by handling ‘information’ in an ‘infonic’ form, though it is an underlying thesis of this work that the concept of an ‘item of information’ *does seem to be an intuitive one.*” [italics added].

It seems to me that any theory of information which focuses on objects and relations between them is likely to interpret information as a thing (cf. Buckland, 1991) that is transmitted between a source and a target. The notion of information as a thing seems to have been partly derived from the transmissional model of information of Shannon & Weaver’s MTC, to which ST is related broadly.¹² It is, therefore, necessary to review MTC briefly at this point.

Mathematical Theory of Communication

Shannon’s Mathematical Theory of Communication is concerned with the transmission of information from a source to a receiver over a physical communication channel, more specifically, data transmission rate of channels, and coding schemes to maximize the level of data compression. Both the source (S) and the receiver (R) are characterized by the number of states that they occupy and the probability distribution over the states.¹³ The average amount of information associated with S (or R), in other words, the average amount of information it can generate is known as the *entropy* of S , and given by:

$$H(S) = - \sum_i^N \Pr(S_i) \log_2 \Pr(S_i) \quad (1)$$

where $\Pr(S_i)$ is the probability of S being in state i , and N is the number of states S can occupy. For instance, for a source that can generate 8 distinct symbols where the probability of each message being generated is equal, $N = 8$ and $\Pr(S_i) = 1/8$. Information generated when a particular symbol is selected from a set of possible symbols is called the *self-information* or *surprisal*, which measures the uncertainty associated with the selection of the symbol, and given by:

$$I(S_i) = -\log_2 \Pr(S) \quad (2)$$

For N equiprobable symbols, Equation (1) reduces to (2). For example, when $N = 8$, both $H(S)$ and $I(S_i)$ are equal to 3 bits.

The rate of transmission between S and R , or how much information there is in R about S is given by:

$$R(S; R) = H(S) - H(S|R) \quad (3)$$

where $H(S|R)$ is the average entropy of S conditional on R , which models the average uncertainty about S in R . When for each state of S there is a state in R that makes it certain such that $H(S|R) = 0$, then R is a perfect indicator of S . $H(S|R)$ can, therefore, be interpreted as a measure of “tracking efficiency” for the joint system (Harms, 2006, p. 232–233).

MTC is a *syntactic* theory of information, as it is not concerned with the meaning of the symbols/messages transmitted but their quantity. In a system of two symbols ($N = 2$), say heads and tails of a coin, 1 bit of information is transmitted regardless of whether the head or tail of the coin symbolizes nuclear war or who is going to do the dishes. Nevertheless, Situation Theory and various other accounts of semantic information have two important connections to MTC (Floridi, 2005):

- The data communication model, comprised of the source (S), the receiver (R), and the channel (C). R contains information about S , i.e. information flows from S to R in C .
- Information flow is defined in terms of transitions in a system’s state space.

These two connections with MTC reinforce the interpretation of information as a thing in ST, a case of reification as discussed earlier.

Other Varieties of Information: Aesthetic, Ethical

Mathematical conceptions of information (e.g., ST, MTC) are congruent with the notion of information known as the “General Definition of Information” (GDI). GDI is explicated in Floridi (2005) as follows [formatting is modified]:

- σ is an instance of information, understood as semantic content, if and only if;
- σ consists of one or more *data* [defined in Floridi as “lack of uniformity within some context”]
- The data in σ are *well-formed*
- The well-formed data in σ are *meaningful*

GDI conceives data and information as things or reified entities (Floridi, 2005). I have referred to conceptions of information, which emphasize things (objects) and the relationships between them, as ontological information. An alternative account of information, which is more appropriate for the purposes of IS, foregrounds the epistemological dimension in cognitive acts. In certain situations, as discussed earlier,¹⁴ the epistemological dimension is more prominent, and can give rise to epistemological information. In other words, certain situations may cause changes in the mind of the agent regarding the sources, scope, and methods of obtaining knowledge, i.e., metatheoretical *rules* of knowledge acquisition. This is related to but distinct from the knowledge of the

state of affairs in the world.¹⁵ I suggest that there are types of information other than factual (ontological) and epistemological. Similar to arguments put forward for epistemological information, it is possible to argue that certain situations could give rise to changes in the metatheoretical rules concerning aesthetics and ethics in the mind of an agent. In other words, a situation could cause a change or revision in the rules by means of which one passes an aesthetic or moral judgment.

The relationships between epistemological, aesthetic, and ethical varieties of information are complex. One quality they share is the critical attitude they hold toward value standards, respectively, in knowledge, cultural, and moral domains. In this sense, they all involve prescriptive/performative acts. For instance, Habermas (1981, p. 20) notes that that in aesthetic criticism “. . . the adequacy of value standards, the vocabulary of our evaluative language generally, is made thematic.”¹⁶

I conclude this section by modifying (a part of) the taxonomy given in Floridi (2005). Floridi divides semantic information into two main classes: instructional and factual. He considers factual information as the mainstay of the philosophy of information. My modified taxonomy includes epistemological, aesthetic, and ethical information as subdivisions of instructional/prescriptive information, which are the mainstay, in my opinion, of the philosophical approaches to semantic information from the perspective of IS:

- Semantic Information
 - Prescriptive (“Instructional” in Floridi)
 - Epistemological
 - Aesthetic
 - Ethical
 - Ontological (“Factual” in Floridi)

Varieties of Logic: Formal and Informal

A logic consists of a formal or informal language¹⁷, a deductive apparatus and a model-theoretic semantics. The deductive apparatus or inference rules provide formal mechanisms for making valid inferences, and the semantics to codify the truth—or possible truth—conditions (Shapiro, 2000). Inference rules determine how conclusions are drawn from premises. It is generally agreed that there are three different inference types: *deduction*, *induction*, and *abduction* or *hypothesis*. Deduction is the type of reasoning that formal logics aim to formalize. The differences between the three inference types can be illustrated with the following example (Peirce, 1958, vol. 2, para. 623)¹⁸ [formatting is modified]:

Deduction

Rule – All the beans from this bag are white. [given]
 Case – These beans are from this bag. [given]
 Result – These beans are white. [concluded]

Induction

Case – These beans are from this bag. [given]
 Result – These beans are white. [given]
 Rule – All the beans from this bag are white. [concluded]

Abduction [“Hypothesis” in the original]

Rule – All the beans from this bag are white. [hypothesized]

Result – These beans are white. [given]

Case – These beans are from this bag. [concluded]

Of the above, deduction is the only type of reasoning which guarantees true conclusions from true premises. It is a type of argumentation from general to particular. Induction is an argument from particular to general, which produces only probable conclusions that need to be verified by future observations (Burch, 2006). Abduction is different from both of the above types of inference. It is a creative process of hypothesis forming; based on the relevant evidence, the hypothesis that best explains a given phenomenon is formulated. Since it allows conclusions that are not guaranteed to be true, it is not part of classical logic. However, for Peirce it is the only type of logic that can produce new knowledge, and as such is a fundamental part of scientific reasoning. According to Peirce “Abduction is the process of forming explanatory hypothesis. It is the only logical operation which introduces any new idea” (Peirce, 1958, vol. 5, para. 171–172). The following example illustrates this process:

1. The surprising fact, F, is observed.
2. But if H were true, F would be a matter of course.
3. Hence, there is reason to suspect that H is true (Peirce, 1958, vol. 5, para. 189).

Abductive reasoning has attracted attention from logicians who study *informal logic*. Informal logic aims to understand ordinary use of language and reasoning. It is an attempt to develop a logic which goes beyond the classical logic. Partly as a reaction to deductive models of argumentation required by formal logic, informal logicians study *abductive* and *conductive* models of inference (Groarke, 2007). Conductive arguments are means of reaching strongly suggested but not certain conclusions based on accumulation of non-decisive evidence. Another mode of inference studied by informal logic is *dialectical logic*. In classical philosophy, dialectics is understood as exchange of propositions and counterpropositions (sometimes known as theses and antitheses). The study of dialectics in informal logic has highlighted the importance of context in which arguments take place (Groarke, 2007). However, one needs to turn to Hegelian philosophy in order to fully appreciate dialectical logic in relation to production of hypothesis and new knowledge, as well as the creative process of abduction.

Although known to the ancient philosophers, development of dialectical logic reached its peak in Hegel, especially in his “Science of Logic” (1831/1969).¹⁹ Hegel widened the scope of logic from propositional algebra to the study of the change and development in society and nature (Blunden, 2007). Dialectical logic analyzes the *qualitative* development of things and events, which are construed to be in a continuous state of change. In fact each phenomenon/object incorporates the seeds of its own negation at any point in time, which is the driving force of qualitative change; everything develops eventually into something else. In this respect dialectical logic is seen as the opposite of formal logic, which is founded on the idea of identity and constancy (Stavinsky, 2003). The formal

logic rests on three Aristotelian maxims (Ballantyne, 2008) [formatting is changed]:

1. Law of Identity (A is A);
2. Law of Noncontradiction (A is not non-A);
3. Law of Excluded Middle (Any X is either A or non-A).

In contrast to the mechanical worldview of constancy of identity, dialectical logic holds that the basic rules of correct thinking should reflect a universe, which is in constant flux and qualitative change. The dialectical maxims of correct thinking subsume the three Aristotelian maxims of logical discourse (Ballantyne, 2008):

1. Law of Unity and Struggle of Opposites: Every object or process develops into something else, not only because it is affected by some external force but also because the very components out of which it is made force changes. . .
2. Law of Transition from Quantitative to Qualitative Change: Development cannot take place without discontinuity. . .
3. Law of Negation: Every new stage, while synthesizing in itself the progressive trend of previous stages, contains within itself the preconditions for further development. . .

The dialectical reasoning, therefore, aims to grasp the development of phenomena in time due to constitutive internal contradiction. The key to understanding the dialectical process of qualitative change is, thus, to uncover the contradictions inherent in any social or natural phenomenon at any point in time which drive its development. The dialectical analysis of phenomena/texts, as demonstrated in the next section, requires formulation of an alternative hypothesis (antithesis), which is a creative process similar to *abduction*.

Information Science and Logic

In this section formal and dialectical approaches to reasoning are applied to the analysis of a news article to demonstrate their differences, scope, and applicability to IS. The example text entitled “Roundup: France, Africa seek mutual benefit” (document ID: XIE20030221.0307) is taken from the HARD TREC 2004 corpus (Voorhees, 2005). This document is retrieved in an experiment in response to the query statement “AIDS in Africa” derived from the title field of the TREC topic “HARD-409”²⁰ by a standard IR system. The article reports the results of the 22nd Africa-France Summit held in 2003, which promises economic and social aid to Africa. AIDS is mentioned only in a short section of the article without mentioning anywhere the conventional measures taken to prevent its spread, or the treatment of the sufferers, and hence, evaluated as nonrelevant by the TREC assessors.

I have discussed the subject matter of this document in detail elsewhere, and demonstrated that in contrast to the TREC assessors it could be considered as relevant for certain user groups who see the problem from an alternative theory of causation of AIDS (Karamuftuoglu, 2007). Here, I will analyze the same document first by following a

procedure informed by formal logic, followed by the dialectical approach. These analyses will facilitate the understanding of the roles that could be played by the two approaches in subject analysis, and more generally IS, and will lead to the discussion of the roles formal logic and the philosophy of information could play in the development of information science as a discipline.

Formalist Approach

An approach to subject analysis modeled on the formal logic would start by identifying the rule that drives the deductive syllogism. The TREC topic-narrative given earlier (Endnote 20) would suggest that the enquirer’s main interest is in the measures taken to prevent the spread of AIDS and treat those affected by it. The commonly accepted cause of AIDS is infection by the HIV virus. A document, thus, would be on topic and relevant to the enquirer if it discusses the measures taken to prevent the spread of the HIV virus. The rule to arrive at a relevance judgment would then be “documents that discuss measures taken to prevent the spread of the HIV virus are relevant.” In terms of the deductive syllogism:

Deduction

Rule – Documents that support measures taken to prevent the spread of the HIV virus are relevant.

Case – XIE20030221.0307 does not support measures taken to prevent the spread of the HIV virus.

Result – XIE20030221.0307 is non-relevant.

This was the conclusion reached by the TREC assessors. I will show next how an opposite conclusion is possible when an alternative theory regarding the cause of AIDS is hypothesized.

Critical Approach

Dialectical logic is an important part of critical thinking: “[a]t the core of a genuinely critical methodology lies the application of dialectical logic.” (Wainwright, 1997). While formal logic does not admit contradictory judgments, dialectical logic admits them. In fact, as discussed earlier, it is a mistake of philosophical idealism, according to dialectical thinking, to see things and events as unchanging, self-identical (noncontradictory, equal to itself) entities. A critical approach to subject analysis should, therefore, start at uncovering contradictory or alternative theoretical positions on a given subject matter. The critical realist method of subject analysis developed by Hjørland and his colleagues approaches this task by explicating the alternative theories in a scientific domain (Hjørland, 1992, 1997a; Hjørland & Albrechtsen, 1995). From a dialectical position a document may be both relevant and nonrelevant at the same time to different groups of users, or to the same user group at different points in time.²¹

In the case of the aforementioned news article “Roundup: France, Africa seek mutual benefit,” it appears to be nonrelevant to the query when it is analyzed from the perspective of

formal thinking, as discussed in the preceding section. However, it is argued in Karamuftuoglu (2007) that the same document could be evaluated in a totally different way. First, it is necessary to uncover competing theories of AIDS causation. One such theory is known as the Duesberg (2006) hypothesis, which rejects the etiological explanation that HIV is the cause of the AIDS epidemic. The Duesberg theory explains the AIDS phenomenon in Africa and the developing world in terms of conventional factors, such as malnutrition, parasitic infections, and poor sanitation. However, it is unlikely that the human classifiers would know the Duesberg hypothesis or other alternative theories of the AIDS epidemic, which are not supported by the vast majority of the medical community. Karamuftuoglu (2007) suggests that general education in major paradigms and schools in philosophy and social sciences would help discover alternative theories within which a document acquires its value. To illustrate the process of the discovery of the relevance of a document to a potential community of users, consider the following scenario:

The assessor does not have a rule that when applied to the document XIE20030221.0307 yields a positive judgment. In contrast to the scenario in the preceding section, the assessor in this case applies creative thinking to the problem: “What sort of an etiological theory would make this document relevant to the query AIDS in Africa?” In the form of abductive syllogism:

- The surprising fact, F (document XIE20030221.0307 is relevant to the topic “AIDS in Africa”), is observed (i.e., postulated).
- But if H (there exists an alternative theory of AIDS causation, which explains the AIDS epidemic in terms of social and environmental factors) were true, F would be a matter of course (given that the document reports relevant information on economic and social development of Africa; see below).
- Hence, there is reason to suspect that H is true.

In the above case of abductive logic applied to document evaluation the process is more complex than the case where the (surprising) observation corresponds to a fact. In the case of document evaluation/subject analysis, it is not known whether there exists a user community for whom the document is actually relevant. This is postulated. Based on this postulate and the content analysis of the document, which reveals that it contains information about social and environmental development of Africa, it is hypothesized that there exist alternative theories of AIDS causation, which explain the epidemic in terms of conventional environmental and social factors. The assessor’s knowledge of the major schools of thought in social sciences would obviously be an advantage in formulating this hypothesis. The assessor then needs to research to find whether the hypothesis is true, i.e., there really exist social/environmental explanations of AIDS. Failing to find one would make the document non-relevant. Conversely, discovery of a relevant theory would make the document relevant to a user group, who prioritizes such factors in explaining health problems over virus-based explanations.

Once the Duesberg or a similar theory of the AIDS epidemic is found in the literature the inference process would revert to straight deduction as follows:

Deduction

Rule – Documents that support measures taken to prevent the spread of AIDS in terms of environmental/social factors are relevant.

Case – XIE20030221.0307 supports measures taken to prevent the spread of AIDS in terms of environmental/social factors.

Result – XIE20030221.0307 is relevant.

In the above scenario to successfully go through the inference process the assessor first needed to establish that the document contains significant information about economic/social development of Africa. To single out that aspect of the document content from potentially many others, awareness of the importance of socio-economically oriented modes of inquiry in social and medical sciences would be needed, as noted earlier. This may not be sufficient alone to establish a link between the document and the AIDS epidemic in Africa in the mind of the assessor. Other circumstantial evidence would be needed in practice for the assessor to recognize that the document might be valuable for a certain user group. Arguably, the following information reported in the document provides the basis for a strong *conductive* argument that there could indeed be a link between the document and the topic “AIDS in Africa” (Karamuftuoglu, 2007):

- French President’s and the United Nations Secretary General’s promises for economic aid to Africa to improve the general health and environmental conditions there.
- Mention of the UN Secretary General’s concerns about AIDS in Africa (although no specific reference is made to its prevention from the perspective of the HIV-oriented explanation of the epidemic).
- The presence of South African President Mbeki at the summit who is known for his voiced support for the argument that AIDS is the result of malnutrition, poverty, chronic diseases, and other social/environmental factors.

The potential contribution of the dialectical logic to subject analysis is the importance it attaches to looking at phenomena (thus texts) from opposing viewpoints. In the above scenario, by explicating conflicting viewpoints on the causes of AIDS, our (subject analyst’s) knowledge of the subject moves forward in the dialectical sense. Dialectical method recognizes that the conclusions derived from dialectic analysis of the contradictions constitutive of phenomena need to be tested and verified in the real world; in the above case, based on long-term experiences of people whose lives are affected by AIDS. It also recognizes that values of theories, hence document relevance, change over time as theories become more or less useful to the lives of people. Another potential contribution of the dialectics is that it provides a *teleology* that directs the process of the analysis (see below).

The case of the news article on “AIDS in Africa” provides another example of how an unfamiliar situation could lead to

acquisition of information, which affects the epistemological basis of thinking—epistemological information. The assessor in the above scenario makes a hypothesis that there exist environmentally and socially based explanations of AIDS. The recognition of this possibility is an indication that not only the way the assessor sees the relation between environmental factors and AIDS has changed (ontological information), but also his *theorization* of health in general has changed from virus-based to socially/environmentally based (epistemological information).²²

It seems from the above example that abductive logic first states a conclusion and then fixes the premises that makes the conclusion appear natural in a post hoc fashion. In this way, it transforms itself into deduction. But this is another way of saying that deductive inferences do not carry any new information. In fact there is an ongoing debate in formal logic circles on whether deductions are “tautological” or “analytical,” i.e., the information carried by the conclusion is contained in the information carried by its premises (D’Agostino & Floridi, 2009). Although there are attempts to resolve this so-called “scandal of deduction,” such as in the aforementioned article by D’Agostino & Floridi, there is no generally accepted solution to this paradox thus far. If deductions are tautological, my earlier explanation regarding the formulation of the new hypothesis about the relevance of the document XIE20030221.0307 begs clarification. In the original account the impression is given that when the assessor is aware of socially/environmentally oriented theories in social sciences, and the document contains relevant information about economic/social development of Africa, the formulation of the hypothesis regarding the existence of socially/environmentally oriented theories of AIDS follows naturally, as if in abductive reasoning there exists, nested within it, an inner deductive loop in the reverse direction. However, as noted above, if all deductions are tautological this cannot be the case. The way out of this paradox is the recognition that abductive reasoning or hypothesis forming is not purely a logical, but also teleological or goal-oriented process. In other words, the assessor in our example was able to hypothesize the existence of alternative theories of AIDS not because he followed the rules of formal logic verbatim, but because in the final analysis he *intended* such an explanation over potentially many others. Lawson (1997, p. 212) states that: “Not much can be said about this process of retroduction [abduction] independent of context other than that it is likely to operate under a logic of analogy or metaphor and to draw heavily on the investigator’s perspective, beliefs and experience.” In this context it is interesting to note that according to some dialectics is not a formal axiomatic logic, which sheds light on the paradox of hypothesis forming: “[Dialectics is] not a strictly formal (abstract-general) logic but rather a formal-substantive (concrete-synthetic) one. In other words it constitutes a teleological rather than a tautological system . . . The result of a dialectics investigation must, in other words, stand on its own without depending on any axiom or postulate.” (Sekine, 1998; quoted in Hirsch, 2004).

It is possible to compare subject analysis/classification to science at a miniature scale. Every time a nonmechanical classification decision is to be made, hypotheses need to be formulated, consequences of them are deduced, which are then subjected to experimental testing. This is known as the “hypothetico-deductive” account of science. In the hypothetico-deductive account the leap needed in formulating a hypothesis is unexplained. It is assumed to be an inborn characteristic of creative people (French, 2007, p. 13). An alternative account, as briefly discussed above, is that all science, at least social science, is teleological in the sense that they aim to bring about a certain goal. The goals make sense within a certain set of core values, such as belief in human liberty, emancipation, justice, etc. In this context, Gutierrez (1998) writes that: “Teleology of the explanation corresponds to the *purpose* of the investigator and has to do with the role of *subjectivity* on the foundations of science, with the operation of *non-formal* powers of thought . . . Formalism is useful and indispensable, but its functioning necessitates the complementary full exercise of non-formal, ultimately *unformalizable*, powers of thought.”²³ [italics added].

It can be concluded from the discussion so far that although formal logic may not be useful in eliciting the various meanings of a given document for different user groups, it may still be useful in uncovering more straightforward (denotative in a semiological sense) layers of its meanings. It is in this sense that some critics see formal logic as a means of rendering explicit what is already known (cf. D’Agostino & Floridi, 2009). In the next section I will argue that for this and a number of other reasons formal logic as well as informal and dialectical logics should become a part of standard IS education. However, it should be noted that formal logic on its own is not adequate in establishing a basis for scientific inquiry.

Information in Information Science

Subject analysis and classification are complex processes. Although they have a long history in information science, there are no well-established methods of subject analysis for the human analyst. I have argued in the preceding pages that both formal and informal logics, including dialectics, may have a role to play in the subject analysis process. Of the two approaches, informal logic, in particular abduction, is arguably an inseparable part of any scientific and creative inquiry, to which I will return in the Conclusions section. Formal logic, on the other hand, appears to have a rather limited role to play in subject analysis/classification. As argued earlier, the deductive method seems to help render explicit what is implicitly known, rather than yielding new knowledge, thus, could help the analyst to uncover the more straightforward meanings of a text. However, it may have a more fundamental role to play in IS in general.

Formal approaches to information are criticized from the perspective of information science mainly for being concerned with merely syntactic information. While this is true for MTC, it is not true for others, such as ST. However, most, if not all, formal conceptions of information, including ST,

are concerned with factual, or as I argued in this article, ontological information. Such theories have important roles to play in certain disciplines, such as computer science, where they serve useful functions in algorithmic processing of linguistic and other types of information. For instance, Mutual Information, which is related to a family of probabilistic interpretations of information derived from MTC, is used in many IR-related tasks, such as query expansion (Vechtomova & Karamuftuoglu, 2004; Vechtomova, Robertson, Jones, 2003). However, as I argued in this article, ontologically oriented conceptions of information are inadequate for the purposes of IS, since a good portion of IS work involves interpretation and evaluation of information, not just modeling relations between objects.

My arguments for the importance of the concept of information in IS is not, however, limited to the usefulness of mathematical conceptions of information to IR. The epistemological conception of information, which I have argued to be vital in developing theories of subject analysis and classification, is, although distinct from, congruent with formal logical theories of information. For this reason it is rather unproductive to isolate IS from fields such as the philosophy of information, which studies logical and mathematical models of information. IS in my view has a unique role to play in this regard. While formal logic and the philosophy of information are mainly concerned with factual/ontological information, concepts of epistemological/aesthetic/ethical information are plausible as outlined in this article. IS is uniquely positioned to explore such concepts philosophically, as well as practically, as IS is an evaluative/critical discipline with respect to *content*, whereas *formal* logic is not. Furthermore, as I have argued in a number of articles (Karamuftuoglu, 1998, 2007), IS and IR are concerned with production of new knowledge by establishing connections between specialisms and disparate pieces of information. The common ground between epistemological/aesthetic/ethical information on the one hand and evaluative and knowledge production functions of information science on the other is that they all involve prescriptive activities that are concerned with metatheoretical systems and rules.

IS is still a young discipline. To develop it needs to rise to the challenge of studying “the many different conceptions of information embedded in different theoretical structures” articulated by Capurro & Hjørland (2003). This requires, in my view, removing the conceptual boundaries that constrain IS to the study of a particular type of informational objects—documents. There are recent developments, mainly technological, that make the historical form of the document unfit as the sole unit of analysis in IS, full exposition of which is beyond the scope of the present article. Briefly, online collaborative writing systems such as Wikis and dynamically generated and updated Web content, as well as the ubiquitous hypertext format, are some of the recent technological trends that foreground the sentence or the proposition rather than the whole document as the primary unit of interaction. For this reason it is, arguably, getting harder to think solely in terms of the traditional document form.

IS needs to explore a wide range of tools in order to be able to study the multitude of varieties of information production and use in different situations and contexts. This would imply the incorporation of both informal and formal logics, as well as aesthetics, ethics, and other divisions of philosophy into IS education, since a good deal of informational acts take place in human situations that involve negotiation and evaluation of cultural, moral, and knowledge standards.

Conclusions

There are many conceptions of information satisfying different theoretical needs in different disciplinary contexts. One common thread that binds formal conceptions of information is to treat information as semantic content about the state of affairs in the world. However, such a conception is too limiting for the purposes of IS, as one of the main tasks of IS is to evaluate semantic content. Any evaluation is made from a particular standpoint—*theoretical or metatheoretical rules and standards*, which are subject to negotiation and qualitative change. One can, therefore, speak of not only change in information about the state of affairs in the world, but change in information about the rules and meta-rules of acquiring information about the state of affairs in the world. This is the subject of epistemology, and within this context one can speak of epistemological information that complements ontological or factual information. In a similar vein, one can speak of aesthetic and ethical information to denote changes in the rules/meta-rules that govern aesthetic and ethical value standards. While formal logic and the philosophy of information study mainly factual semantic content, IS is intimately tied to epistemology because of its evaluative role *vis-à-vis* semantic content, i.e., information.

There are limited formal tools that aid information scientists in their evaluative tasks. Formal logic, specifically deductive reasoning, could be of help in analyzing and evaluating information. However, formal logic is inadequate in providing a ground on which a science of information could be founded. This is mainly because science, and, generally, creative activities, are goal-oriented or non-tautological in the sense of being imbued in purpose, values, and non-formal powers of thought. It is, therefore, necessary to study informal logics, in particular abductive and dialectical forms of it, both of which aim to understand qualitative change, and creation or synthesis of new knowledge.

Information scientists need tools such as formal and informal logic, but logic on its own does not yield a science. Information scientists need theories and metatheories to create hypotheses and test them. The foundation for IS in its pursuit of critically studying and evaluating semantic content is, therefore, theories and metatheories in knowledge domains, as well as empirical experimentation and observation. A broadened approach to the science of information, which studies a multitude of varieties of production and use of information in different domains, situations, and technological forms calls for a radical rethinking of the identity of information science as a discipline.

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Endnotes

¹I owe this formulation to Tunalı (2001) and Hartmann (1998).

²By means of constraints and channels, which will be discussed further below.

³Infons could take spatial and temporal locations as arguments to make them more precise. However, I present here only the bare bones of ST, sufficient enough to convey the main idea behind it. See Akman (2009) for full exposition of it.

⁴The correct way to represent this relationship is to use situation types, or simply types, rather than infons as follows: [\dot{s} | \dot{s} |= { <<present, belief; 1>> }] \longrightarrow [\dot{s} | \dot{s} |= { <<present, dogma; 1>> }]. Types generalize infons by parametrizing them. In the above statement \dot{s} is a parameter denoting a situation. This distinction, however, is not important for the purposes of this article.

⁵It is not obvious how ST should handle uncertain information. Rijsbergen & Lalmas (1996, pp. 397) discuss this issue in the context of IR.

⁶Factual information is distinct from instructional or prescriptive information, to which I will return later on.

⁷A constraint is a relationship between types, whereas a channel is an informational link between situations (Dominich, 2001, p. 243). For our purposes this distinction is not significant.

⁸<http://wordnet.princeton.edu/>

⁹The concept of “individuation” implies a certain perspective from which the world is classified. However, this concept is not elaborated further in ST.

¹⁰I thank one of the anonymous referees for raising this point. Bhaskar (2008, p. 16) notes that empirical realism is underpinned with “... the presumed characteristics of the objects of experience, viz. atomic events, and their relations, viz. constant conjunctions.”

¹¹Information art is defined in Karamuftuoglu (2006) as a kind of conceptual art that uses concepts, tools, etc., derived from scientific disciplines, such as biology, genetics, informatics, etc. An example of it is, *Alba*, a genetically modified rabbit that glows in the dark, by the artist Eduarda Kac (<http://www.ekac.org/gfpbunny.html>).

¹²MTC is a syntactic theory of information, whereas ST is semantic. However, they are related for the reasons explained in the next subsection.

¹³The exposition of MTC in this section is based on Harms (2006).

¹⁴Another example of such a situation will be given in the section Information Science and Logic, below.

¹⁵This distinction could also be cast in terms of the difference between “knowledge-how,” which is the main focus of the present article and “knowledge-that,” which is the main focus of epistemic logic.

¹⁶It is beyond the scope of this article to give a full exposition of the concept of aesthetic and ethical information; however, Karamuftuoglu (2006) discusses aesthetic evaluation of works of information art in some detail. In this work, aesthetic value of a work of information art is linked to its contribution to philosophical (ontological, epistemological, methodological) underpinnings of the discipline(s) from which the work derives its concepts, methods, and tools.

¹⁷Example of a formal language is the set of all syntactically correct computer programs written in a computer programming language, such as Java. An example of an informal language is English.

¹⁸All Peirce quotations are taken from Bergman & Paavola (2003).

¹⁹McTaggart (1922) provides a detailed account of Hegel’s philosophy.

²⁰Title: AIDS in Africa. Description: What is the state of AIDS in Africa? Narrative: Little attention has been given to the AIDS epidemic in Africa that has decimated an entire generation of Africans. What is being done to help prevent the spread of AIDS and to treat those already infected? What sorts of public education/health measures have African governments taken? What are the barriers?

²¹There are different opinions whether dialectical logic admits true logical contradiction. For some, a thing is in an inconsistent or contradictory state at two different points in time in its development, therefore there are no true logical contradictions in dialectics. For others there are true logical contradictions, especially in Hegel (cf. Priest, 2008). In my application of it to subject analysis here, it is both a contradiction in time and for different user groups, therefore not a true logical contradiction. However, in my opinion different interpretations of the dialectic contradiction depends on the particular theory or metaphysics of time, and may not be antithetical to each other as it may appear at first sight. For instance, in Bergson’s philosophy, past, present, and future exist simultaneously (Bergson, 1896/1911).

²²It is worth reiterating the point I made earlier regarding the two aspects of epistemological or epistemic information. By epistemological information I emphasize the changes or revisions made in the mind of the agent regarding the theories about the sources, scope, and the methods of obtaining knowledge, i.e., metatheoretical *rules* regarding acquisition of valid knowledge. This is not the same as the agent’s knowledge/beliefs about the state of affairs in the world (i.e., objects and the relations that hold between them), which are usually the focus of interest in formal approaches to epistemology (epistemic logic).

²³Parallels to the above line of thought can be found in Lacan’s philosophy. In Lacan “the Real” remains outside the realm of “the Symbolic,” implying that it cannot be fully formalized (Glowinski, et al., 2001).

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