INFORMATION AS A NATURAL AND SOCIAL OPERATOR

Joseph E. Brenner and Mark Burgin

***Abstract**: The emphasis of this paper is on the analysis and characterization of information as a natural and social operator, especially in areas of current interest of information science and in the individual cognitive and group domains. We first present an extensive classification of operators according to various criteria including function and target. Support for our approach comes from a recently proposed extension of logic to real phenomena, Logic in Reality (LIR). By focusing on the nature and properties of operators in social environment, such as organizations and networks, we acquire a possibility to achieve a more rigorous logical discussion of evolutionary processes in the knowledge-centered Information Society, demonstrate abundance of natural operators, explain how information operates in nature, and analyze the intentionality of information in human operators. Explicit references to operators have not generally been made in currently discussed theories of information, except to the extent that ascription of effective causal properties to information implies the existence of agents and hence of operators. We examine three representative theories of semantic, semiotic and pragmatic information from this perspective. The concept of information-as-operators is proposed in this paper as a contribution to the discussion of the general properties of information. It is not intended as a complete General Theory of Information, but it is compatible with theories that emphasize the ontological, causal powers of information processes.*

***Keywords:** information, logic, operator, natural, society, semantics, energy, process*

Introduction

Rationale and Objective

An important general notion that has received little rigorous attention, and yet has implications for science and philosophy in general and information in particular, is that of an *operator*. Compartmentalized formalized conceptual definitions of operators are used in mathematics, physics, logic, programming languages, and linguistics. In everyday language informal notions of operators refer to people performing familiar activities in the domains of machines, medicine, organizations and social activity. However, to our knowledge, neither a comparative study of operators and their substrates or operands in different areas, including society, has been made nor a general theory of operators constructed.

At the same time, the broad intermediate domain of non-mathematical real phenomena in which a causal impact is exerted by a person or entity that performs an operation and is, accordingly, an operator should have a place in a comprehensive theory of operators. In this paper, we develop in some detail the notion of such "natural" operators. We first position them as the proximal causes of real change in a framework that includes the well-accepted symbolic and physical operators and show the interrelationships that are prevalent in nature, mind and society. We then proceed to the major objective of this paper which is to study information as a natural and social operator, explicating the role of information in nature and society and outlining the place of informational operators in the emerging Information Society.

Outline of the Paper

In Section 1, we give basic definitions derived from general operator theory, specifying basic classes of operators and their properties, providing a new logical and methodological framework essential for operator studies. Section 2 explains the logic of natural operators related to Logic in Reality [Brenner, 2008]. Section 3 defines and analyzes information as a natural operator and Section 4 studies information as a social operator. Section 5 reviews some current theories of information, in particular semantic and semiotic approaches, from our logical and operational perspective. Our final Section presents our conclusions and indicates some possible directions for further research.

1 The Definition, Classification and Logic of Operators

The most general definition of an operator, encompassing all kinds of operators that are studied and utilized in mathematics, logics, physics, economics, computer technology and science, networking and other fields is the following:

Definition O1: An *Operator* is an object (system) that operates, *i.e.*, performs operations on, some object, system or process, the *Operand*.

Definition O2: *Operand* is an object, system or process operated by an operator.

Being an operator or an operand is a role and a characteristic of a system. One and the same system/object can be an operator in some situations and an operand in other situations, and an operator with respect to some systems and not an operator with respect to other systems. All operators are systems, but not all systems are operators, since subsequent to their formation, some may exist in substantial isolation from their environment to all intents and purposes.

Symbolic and natural operators function in a variety of areas: linguistic operators operate language structures; topological operators operate in and on topological spaces; standard logical operators operate in standard logic; network operators operate in networks; program operators operate data processed by computers and other information processing systems; bus and plane operators operate buses and planes respectively, and so on.

To put some order into this diversity of operators, we have suggested the following framework of operator classifications. On the first level of this framework, operators are primarily classified by three basic parameters: *form*, *operational medium* and *target*.

- Form-oriented Classification: *symbolic*, *material*, and *mental* operators

- Medium-oriented Classification: *social*, *nature*, and *technology* operators – according to the locus of function

- Target-oriented Classification: *socialized*, *symbolized*, and *naturalized* operators - according to the type of operand. This classification includes systems, functions and processes as both operators and targets.

Note that it is possible that an operator has different medium and target types. For instance, social operators are an important sub-class of natural operators, but they can and often do work with symbols, *e.g.*, a writer, and thus, is a symbolized operator. Software systems are technology operators, which work with symbols and thus, are also symbolized operators. Besides, the same system, *e.g.*, an individual, can work both in nature and society. This means that this system can be both a social and nature operator.

At a second level of classification, the basic parameters are *existential* and *goal-oriented*:

- Existential Classification: *natural*, *artificial*, and *hybrid* operators – according to kind
- Goal-oriented Classification: *cognitive*, *search*, and *system construction* operators – according to objective
- Dynamic Classification: *system*, *function* and *process* operators

1.1 Symbolic and Natural Operators

For the purposes of this discussion, the most important distinction to be made is between natural and symbolic operators. Both share the function of capacity to cause abstract or real changes, but the former, invariant, never have a specific meaning of their own, while the latter may embody intentionality and meaning, and some can be considered as processes in their own right.

A typical group of symbolic operators are the constants of standard propositional and predicate logics. These constants are thus operators that, whether or not they are abstract symbols or natural language words, are symbolic in the sense of being expressions in a language that, unlike non-logical expressions, never have a specific *meaning* of their own, but the *function* of determining the logical form or structure of propositions and arguments. They are designators of semantic values, that is, truth-functional in their own right, operators that insure preservation of truth between antecedent and consequent propositions.

Elsewhere, Burgin has shown that the symbolic operators can be derived from natural operators, the latter being primitive. The relation between them is then the same as between a logic of real processes (Logic in Reality; LIR) and the abstractions of standard logic, namely, of ontology to epistemology.

1.2 The Problem of Logic

The current literature on information is vast. Any analysis purporting to identify any generally applicable principle can only refer directly to a minute percentage of it. On closer inspection, however, theories of information tend to repeat a relatively small number of underlying ideas or concepts. These include spontaneity, simultaneity and self-organization which play key roles in the description and explication of the partly intuitively perceived interactions between agents and processes at various levels of complexity. Although many theories do not use standard bivalent logic or its modern modal or deontic versions as such, the basis of reasoning remains that of classical logic, through the use precisely of classical notions of categorial separation, causality, determinism/indeterminism and space-time.

As proposed by Brenner, a new kind of logic, applicable to real systems and phenomena seems necessary as a "missing ingredient" required for a rigorous theory that meets these requirements. We suggest that such a logic is the non-propositional, dialectic "Logic in Reality" (LIR) that he have recently described [Brenner, 2008]. In our opinion, this would be an advance on currently available theoretical foundations of a not only information but theories of society and economics in which the underlying logic is essentially bivalent classical logic, a logic of "exclusion". Indeed, Barinaga and Ramfelt [Barinaga and Ramfelt, 2004], quoting Manuel Castells, stated that one of the challenges of the "network society" is that its very *logic* is based on an idealized, one-sided conception of society that excludes an important part of the world population.

In this paper, we show the close relation between our general approach to operators and the principles of LIR as they impact the theory of information in various ways.

2 THE LOGIC OF NATURAL OPERATORS

2.1 The Axioms and Ontology of Logic in Reality (LIR)

Logic in Reality (LIR) is a new kind of logic that extends the domain of logic to real processes and is applicable to complex interactions and/or operations at the level of individuals and society, as well as relating them to a new underlying metaphysical perspective. Based on the work of Lupasco, LIR is grounded in a particle/field view of the universe, and its axioms and rules provide a framework for analyzing and explaining real world entities and processes, including information, at biological, cognitive and social levels of reality or complexity [Brenner, 2010a].

The term "Logic in Reality" (LIR) is intended to imply both 1) that the principle of change according to which reality operates is a *logic* embedded in it, *the* logic in reality; and 2) that what logic really *is* or should be involves this same real physical-metaphysical but also logical principle. The major components of this logic are the following:

- The foundation in the physical and metaphysical dualities of nature
- Its axioms and calculus intended to reflect real change
- The categorial structure of its related ontology
- A two-level framework of relational analysis

Details of LIR are provided elsewhere. Stated in a compressed form, the most important concepts of LIR are:

1) every real complex process is accompanied, logically and functionally, by its opposite or contradiction, but only in the sense that when one element is (predominantly) present or actualized, the other is (predominantly) absent or potentialized, alternately and reciprocally, without either ever going to zero (the Axioms of Conditional Contradiction and Asymptoticity);

2) the emergence of a new entity at a higher level of reality or complexity can take place at the point of equilibrium or maximum interaction or "counter-action" between the two (the Axiom of the *Included* Middle).

Together, these contradictional relations will be referred to as the Principle of Dynamic Opposition (PDO) of LIR. It can be roughly visualized in Figures 1 and 2.

Principal Directions:	*Potential* → *Actual* (Actualization)	*Actual* → *Potential* (Potentialization)
Entities:	*Identity* (Homogeneity)	*Diversity* (Heterogeneity)

Figure 1. Process Change: LIR Non-Contradiction

Principal Direction:	*Semi-Actuality* and *Semi-Potentiality*
Entity:	*Emergent* T-*State*

Figure 2. Process Change: LIR Contradiction (Counteraction)

These figures show the relation between LIR and the Triadic systems of Burgin in processes of change: processes can move in three directions, two toward non-contradiction as their LIR identity or diversity increases and one toward (maximum) non-linguistic contradiction, a T-state from which a new entity can emerge. All of these are considered aspects of the *logic* in reality. (In standard logic, of course, the contradiction at the point of semi-actuality and semi-potentiality simply invalidates a proposition.) Unlike the Hegelian triad of thesis, antithesis and synthesis, terms in which represent diachronic processes, the LIR changes can be synchronic, with the initial elements and the emergent ones present at the same time, having different degrees of actuality and potentiality. At the same time, no processes in LIR are 100% "pure", that is, non instantiating, in part, the opposite or "contradictory" phenomenon.

LIR should be seen as a logic applying to processes, in a process-ontological view of reality [Seibt, 2009], to trends and tendencies, rather than to "objects" or the steps in a state-transition picture of change [Brenner, 2005]. Stable macrophysical objects and simple situations, which can be handled by binary logic, are the results of processes that go in the direction of a "non-contradictory" identity. Standard logic underlies the construction of simplified models, which fail to capture the essential dynamics of biological and cognitive processes, such as reasoning [Magnani, 2002]. LIR does not replace classical binary or multi-valued logics but reduces to them for simple systems. These include algorithmically chaotic systems, which are not mathematically incomprehensible being computational, that is, built by algorithms, because their elements are, as a rule, *not* in an appropriate interactive relationship. Such interactive relationships, to which LIR applies, are characteristic of entities with some form of internal representation, biological or cognitive.

A major component of LIR is its categorial ontology in which the sole material category is Energy, and the most important formal category is Dynamic Opposition. From the LIR metaphysical standpoint, for real systems or phenomena or processes in which real dualities are instantiated, their terms are *not* separated or separable! Real complex phenomena display a contradictory relation to or interaction between themselves and their opposites or contradictions. On the other hand, there are many phenomena in which such interactions are not present, and they, and the simple changes in which they are involved can be described by classical, binary logic or its modern versions.

Therefore, LIR in a new way approaches the unavoidable cognitive problems that emerge from the classical philosophical dichotomies, such as *appearance* and *reality*, as well as the complementary concepts of *space*, *time* and *causality*, which are categories with separable categorial features, including, for example, final and effective causes. Non-Separability underlies a quantity of metaphysical and phenomenal dualities of reality, such as *determinism* and *indeterminism* (see below), *subject* and *object*, *continuity* and *discreteness*, *internal* and *external*, and *simultaneity* and *succession*. This is a 'vital' concept: to consider process elements that are contradictorially linked as separable is a form of a category error. The claim is that Non-Separability exists on the macroscopic and on the quantum levels, providing a principle of organization or structure in macroscopic phenomena that has been neglected in science and philosophy.

2.2 Natural Operators of the LIR Calculus

The *function* and *process* information operators in the General Theory of Information [Burgin, 2010] provide the basis for a more formal characterization of the calculus developed by Lupasco and outlined in [Brenner, 2008]. The connectives, that is, what is usually defined as the symbolic logical operators of implication, conjunction and disjunction, all correspond in LIR to real operators on real elements in the evolution of real dynamic processes. Accordingly, these operators are, also, subject to being actualized, potentialized or in a T-state . They operate not on theoretical states-of-affairs or propositions, considered as the abstract meaning of statements, but on events, processes and properties, where properties also have the character of processes.

The key concept is that LIR operators themselves must be considered as processes, subject to the same logical rules, fundamental postulates and formalisms as other real and hence, natural processes. This answers a potential objection that the operations themselves would imply or lead to rigorous non-contradiction. Real processes are, accordingly, seen as constituted by series of series of series, etc., of alternating actualizations and potentializations. These series are not finite, however, in reality, processes do stop, and they are thus not infinite. Following Lupasco, we use the term transfinite for these series or chains, which are called ortho- or para-dialectics.

Consequently, terms of LIR as a formal logic develop into a transfinite series of disjunctions of implications. Every implication is related to a contradictory negative implication in such a way that the actualization of one entails the potentialization of the other and that the non-actualization non-potentialization of the one entails the non-potentialization non-actualization of the other. This leads to a tree-like development of chains of implications, which represent the form of evolution of all complex processes. This development in chains of chains of implications must be finite but unending, that is, transfinite. It is a principle of the Lupasco system that both identity and diversity must coexist, to the extent that they are opposing dynamic aspects of phenomena and consequently subject to its axioms. The reader is referred to [Brenner 2008] for details of the applicable non-standard calculus.

One of the areas of application of these natural operators is, of course, language! However, the issues and relations addressed are much more complex than by standard linguistic operators. Ghils [Ghils, 1994] has shown, for example, that the spatio-temporal dialectics in the linguistic theory of Roman Jakobson is best described by the movement between actual and potential, using the corresponding operators as expressed by the Lupasco (LIR) calculus.

The natural operators of Logic in Reality are extremely complex, being both symbolic, material and mental, but also in part symbolized, naturalized and social, since implication, conjunction and disjunction obviously also function within social systems.

These series of series of symbols are at the heart of the LIR representation of reality, since they relate both 1) levels of reality and the processes that are predominant at those levels of reality; and 2) the trends that described toward non-contradiction (identity, homogeneity or diversity, heterogeneity) or toward contradiction (emergence of new entities). Thus the first, positive ortho-deduction represents the formal dynamic aspects of macrophysical, inorganic matter, tending primarily toward a *non-contradiction of identity* according to the 2nd Law of Thermodynamics. It provides a rationale for the existence of (relatively) stable physical objects. Negative ortho-deduction describes the tendency toward a *non-contradiction of diversity* which is characteristic of the biological level of reality and provides for the emergence of new forms and entities, ultimately based on the Pauli Exclusion Principle for electrons.

The third ortho-deduction describes a contradictorial dialectics, the movement toward *contradiction*, and the emergence of T-states involving highly organized states of matter/energy/information at the microphysical level, and at higher cognitive and social levels, especially, those of science and art; and, perhaps, at cosmological levels of reality. As a final remark, the same picture applied to conjunction and disjunction as opposites provides the basis for a non-classical set theory, in which there is no absolute separation between sets and their members. According to de Morgan duality in classical logic, conjunction and disjunction are not *independent*, in the sense that a complementation operator takes any proposition to a similar one with the negative and operation inversed. This duality, however, still refers to a relation between abstract entities.

The picture of reality that is conveyed by the transfinite aspects of the above calculus is that all of the process movements described are in progress at the same time, to a greater or lesser extent, interacting with one another. What this means is that any process must be looked at as the resultant of a highly complex set of microprocesses, which nevertheless share the same structure, reflecting the basic principle of dynamic opposition and the axioms of LIR at different scales, in a fractal manner. The existence of these series of microprocesses, involving several co-existing trends, is the basis for all subsequent discussion of the various applications of LIR.

3 Information as a Natural Operator

In the General Theory of Information of Burgin, information is characterized by a system of principles [Burgin, 2010]. The second of his Ontological Principles, the General Transformation Principle O2, describes the essence of *information* in a broad sense as the potential (capacity) of things, both material and abstract, to cause changes (transform) other things. When this capacity (potential) is actualized, it becomes a nature or technology *operator*, which acts on different systems. The operational essence of information is further emphasized by an Ontological Principle O5, the Interaction Principle, which states that transaction/transition/transmission of information takes place only in interaction. Thus, it is reasonable to distinguish *potentialized and actualized* components of information, whose evolution follows the pattern of Logic in Reality, as discussed above.

3.1 Energy as Information

Energy is information in a broad sense [Burgin, 2010], according to the Ontological Principle O2, and thus the most basic natural operator. According to Smolin [Smolin, 1999], the three-dimensional energetic world is the flow of information. In a similar way Stonier [Stonier, 1991] asserts that structural and kinetic information is an intrinsic component of the universe, independently of whether any form of intelligence can perceive it or not. From this point of view, natural information operators are present in all natural systems.

The aspects of information that justify its designation as a natural operator emerge from theories that give a fundamental role to information in existence. For example, Thompson [Thompson, 1968] asserts that "the organization is the information", and Scarrott [Scarrott, 1989] writes that every living organism, its vital organs and its cells are organized systems bonded by information, which operates organisms, organs and cells.

Reading also writes [Reading, 2006], "one of the main impediments to understanding the concept of information is that the term is used to describe a number of disparate things, including a property of organized matter …" He considers energy and information as the two fundamental causal agents, *i.e.*, natural operators, acting in the natural world.

Overextending this approach, Bekenstein [Bekenstein, 2003] and others have claimed that the physical world should be seen as being made of information itself. However, we reject this and the even more radical point of view expressed by Wheeler [Wheeler, 1990], who claimed that every item of the physical world is information-theoretic in origin. In this view, all such information would be indeed be composed of a multitude of information operators, *e.g.*, information in an instruction is an information operator, a *system* or *function* operator. Brenner [Brenner, 2010], however, points out that views such as those of Wheeler and Bekenstein can lead to some misunderstandings about the correct ontological relation of priority between information and matter-energy. It is the latter that is primitive, and failure to recognize this has often led to unnecessary idealizations of the concept of information.

The issue of the 'physicality' of information is the subject of intensive on-going debate (information as a "physical essence"). Crutchfield [Crutchfield, 1990] treats information as "the primary physical entity from which probabilities can be derived." Landauer [Landauer, 2002] stresses, information is inevitably physical. However, it is more reasonable not to claim that information itself is a physical essence but to suggest that people observe information only when it has a physical representation. Thus, all information in social organization and communities requires some physical form for its content to be transmitted.

Information exists in the form of *portions of information*. Informally, a portion of information is or can be considered (treated) as a separate entity. For instance, information in a word, in a sentence or in a book is a portion of information. Each such portion is an operator in its own right. Thus, we can conclude with Kaye [Kaye, 1995]:

"Information is not merely a necessary adjunct to personal, social and organizational functioning, a body of facts and knowledge to be applied to solutions of problems or to support actions. Rather it is a central and defining characteristic of all life forms, manifested in genetic transfer, in stimulus response mechanisms, in the communication of signals and messages and, in the case of humans, in the intelligent acquisition of understanding and wisdom". In other words, natural information operators are pervasive in all walks of life.

3.2 Information in Natural Objects and Processes. DNA and Evolution

Information present in natural objects is a natural operator. A well-known example of such information is genetic information stored in DNA.

In his book “The Touchstone of Life", Loewenstein [Loewenstein, 1999] persuasively demonstrates that information is the foundation of life. To do this, he gives his own definition of information, the conventional definition of Hartley-Shannon information theory being inapplicable. According to Loewenstein, information, in its connotation in physics, is a *measure of order* – a universal measure applicable to any structure or system. It quantifies the instructions that are needed to produce a certain organization. "The pivotal role of DNA for all living beings made it clear that life as a phenomenon is based on biological structures and information they contain. Information encoded in DNA molecules controls the creation of complex informational carriers such as protein molecules, cells, organs, and complete organisms. As a result, genetic information plays the role of an operator for protein molecules, cells, organs, and complete organisms.

Information plays an important role in evolution, as in the elegant theory of evolution developed by Csanyi [Csanyi, 1989] and Kampis [Kampis, 2002]. Burgin and Simon [Burgin and Simon, 2001] also demonstrated that information has been and is the currently prevailing force for evolution both in nature and society. Smith and Szathmary [Smith and Szathmary, 1998; 1999] discuss evolutionary progress in terms of radical improvements in the representation of biological information. All these processes are initiated and controlled by information present as a natural operator.

3.3 Information and Self-Regulation

Information as a natural operator is very important for self-regulation of various systems in nature. Self-regulation in a broad sense is the property of a system to regulate its internal environment (state self-regulation) and external behavior or functioning (phase self-regulation) in order to maintain a stable, constant condition. Any self-regulating system is an operator, specifically, a *self-operator*.

An important peculiarity of biological systems, such as organisms, ecosystems or the biosphere is that most parameters of these systems must stay under control within a relatively narrow range around a certain optimal with respect to existing environmental conditions. Thus, to achieve stability in its functioning, a biological system performs self-regulation, becoming a self-operator. In this process, the impact of the environmental information operators provides information about outer changes. The impact of the organism information operators provides information about the current state of the self-regulating system, and the self-regulation module of the system applies its information operators to maintain the functioning of the system.

All self-regulation mechanisms have three interdependent basic components for the system feature, *e.g.*, a system parameter, being regulated, as follows: 1) the receptor system is the sensing component that monitors and reflects changes in the system and its environment, receiving corresponding information, and sends information about these changes to the control unit; 2) the control unit processes information that comes from the receptor, formatting instructions (operational information) to the effector; 3) the effector system is the acting component that changes in the system state, *e.g.*, a system parameter, and/or system behavior (functioning). Changes in the system state usually involve sending and receiving information about the state and intended changes.

Information has a pivotal role in the self-regulation of a system seen as its feedback. It is possible to understand self-regulation through the interplay of positive and negative feedback cycles in which some variations tend to reinforce themselves, while others tend to reduce themselves. Both types of feedback are important to self-regulation: positive feedback because it increases parameters of the system (up to the point where resources become insufficient), while negative feedback because it stabilizes these parameters.

Feedback is central to operation of various biological mechanisms, such as genes and gene regulatory networks. In essence, repressor and activator proteins, acting as operators, create genetic operons, which function as feedback loops. These feedback loops may be positive or negative.

A similar situation exists in psychology, when the body receives a stimulus from the environment or internally from its parts, causing the release of hormones. The stimulus is the result of information operators action.

4 Information as a Social Operator

Information acts not only in nature but also in society, accordingly becoming (in the sense of Lupasco [Lupasco, 1973 and Prigogine [Prigogine, 1980] a social operator, the role of which is essentially important in the modern Information Society. Sociologists came to the conclusion that information is the primary capacity for social action, becoming the dominant control mechanism in society. With the advancement of the Internet and other means of informational technology, this role of information constantly grows. As Bell writes, "what counts is not raw muscle power or energy, but information … "

The most common notion of an operator in society is of a human being having control over the flows and use of knowledge and information [Castells, 2000]. For instance, a communications operator answers calls from internal and external sources. Data capture operator is primarily responsible for the accurate data entry of incoming documents as specified by system requirements.

The operator approach to information as having causal efficacy in the society is somewhat different. The causal role or impact thus goes beyond the pragmatic consequences of the operation of quantitative informing about certain facts, which includes knowing that certain sentences are true in semantic theories of information or how to achieve simple results. As pointed out by Leydesdorff [Leydesdorff, 2010], interactions between and among human beings are by definition reflexive, and can be considered as the basic operation of a social system. In turn, interaction between human beings usually is or includes communication, which is an exchange of information. The double contingency in which two individuals entertain (anticipate) expectations provides the basis for the formation of groups. Logic in Reality establishes the logical basis for the reciprocity of the interaction between 'self' and 'other'.

In contemporary society, the importance of information is much higher and continues to grow rapidly. The application of information is one of the key sources of growth in the global economy, acting as both a social and economic operator. For a broad discussion of the emerging information-based Economy, we refer the reader to Leydesdorff [Leydesdorff, 2006]. One of the consequences of information being a social operator in an economic environment is that information has become the key strategic asset for the 21st century. Every organization must invest in developing the best strategy for identifying, developing and applying the information assets – networks, processes and methods - it needs to succeed. Information operates (the behavior of) people, social organizations and social institutions and to stay competitive, companies must implement training and continual development programs to help maintain an efficient level of information resources utilization. When an organization seeks to improve its performance, information feedback helps to make required adjustments. As we have seen in the previous section, this feedback is the result of actions of various information operators.

Information can operate its operands - physical objects, individuals, social organizations and social institutions – directly or indirectly. When a person operates something, for example, raw materials, using some tool, *e.g.*, a machine, then this tool also becomes an operator or more exactly here, an agent. To perform its functions, information in organizations also utilizes intermediate agents. Taking information about tentative innovations in a company, for example, information how to produce new competitive product, *e.g.*, a new computer, car or plane, a company employs researchers who create this knowledge, boards of directors who plan the innovations, and different managers and workers who implement them as intermediate agents.

Information operates society by creating new forms of interaction (by telephone, regular mails, e-mails, etc.), new professions, (programmer, phone operator, mailman, etc.), new economic areas, new activities (blogging, networking, programming, etc.) and in relation to new social problems (on-line security, information gap, etc.).

A peculiarity of information, especially as a social operator is that it can be (and usually is) an operator and an operand at the same time. Indeed, throughout history, people have always tried to manage their information as best they could, introducing new ideas, new methods, new processes and new strategies that enabled separate individuals, social groups and society as whole to better think and work. However, in the Information Society, individuals, teams, organizations, and between organizations have to find new ways to efficiently manage information. Researchers started to search radical and fundamentally new ways to accelerate information processes, such as identifying, creating, storing, sharing and applying information. In all these processes, information becomes an important actor, assuming the role of an operator and displaying the feature of self-operation. In essence, information as a natural operator is very important for self-regulation of various social systems.

For instance, along with labor, capital, and natural resources, information has become a primary factor of production, as well as a product sold in the market as a commodity. The first aspect displays information as a social operator, while the second one shows that information is an operand for various operators.

5 Operators and Theories of Information

As noted in Brenner [Brenner, 2011] on the Metaphilosophy of Information of Wu Kun (see below, Section 5.4) a major problem in the theory and philosophy of information is disentangling its ontological and epistemic properties. Burgin [Burgin, 2010], in his General Theory of Information, has proposed the concept of "infological systems" as part of the characterization of informational systems and processes that emphasizes their ontological aspects (the term is a contraction of informational-ontological). The theories of information indicated for discussion here are listed in increasing order of ontological commitment, implying increasing relevance of Logic in Reality to their dynamics.

5.1 Semantic Theories

The General Theory of Information enables a constructive definition of semantic information. To do this, one chooses the system of semantic structures as the infological system. The information involved in an infological system is, roughly, defined as both constituted by and acting upon structural subsystems which we designate as its infological system. For example, systems of knowledge are infological systems.

Then we come to the following definition:

Definition: *Semantic information* is information that changes (has a potency to change) semantic structures, *i.e.*, structures that represent meaning.

In this context, semantic information becomes an information operator that acts on semantic structures. In the majority of semantic information theories, transformations of an infological system such as a thesaurus, or system of knowledge, are treated as information, making the thesaurus an operand of the semantic information operator. The founders of the semantic approach, Yehoshua Bar-Hillel and Rudolf Carnap built semantic information theory as a logical system [Bar-Hillel and Carnap, 1952; 1958]. They wrote that their theory lies explicitly and wholly within semantics, being a certain ramification of the Carnap's theory of inductive probability [Carnap, 1950].

They considered the semantics of sets of logical propositions, or predicates that assign properties to entities. Propositions are non-linguistic entities expressed by sentences. A basic proposition/statement assigns one property to one entity. An ordinary proposition/statement is built of basic statements by means of logical operations. For the universe of entities, the state description of such a universe consists of all true statements/propositions about all entities from it.

Later many researchers contributed to this area. One of the most important contributions was made by Hintikka, who with his theory of constituents and constructions of the surface and depth information further developed the approach of Bar-Hillel and Carnap [Hintikka, 1968; 1970; 1971].

A different approach to semantic information was suggested by Donald MacKay, who assumed that the information process is the cornerstone for increase in knowledge [Mackay, 1969]. In his theory, the information element is embedded by the information process into knowledge as a coherent representation of reality.

Mackay writes: "Suppose we begin by asking ourselves what we mean by information. Roughly speaking, we say that we have gained information when we know something now that we didn't know before; when 'what we know' has changed."

According to MacKay, meaning is the selective function of the message on an ensemble of possible states of the conditional probability matrix. In this context, the three types of meaning are represented by the *intended selective function*, the *actual selective function*, and the selective function on a conventional symbolic representational system, correspondingly. Thus, meaning is treated as a selection mechanism that may give information to a system if it changes the system's state.

A similar concept of information is utilized in the approach that was developed by Shreider and also called the semantic theory of information [Shreider, 1965; 1967]. The notion of a thesaurus is basic for his theory. As any thesaurus is a kind of infological systems, this approach is also included in the general theory of information.

One more approach to semantic information was suggested by Floridi, who based it on treating information as well-formed, meaningful data [Floridi 2004]. His definition does not require a concept of more than symbolic operators, corresponding to those of standard bivalent logic. In a similar way, the conception of strongly semantic information suggested by Sebastian Sequoiah-Grayson [Sequoiah-Grayson, 2007] moves away from a notion based on probability values, which can be more easily related to the variables of Logic in Reality to one based solely on truth–values. This theory of strongly semantic information is useful as a basis for judgment of the value of explications of the pre-theoretical notion of information.

It is necessary to explain that the conjecture that "information is meaningful data" suggested by Floridi contradicts the practical understanding of data in such areas as databases and data management. To show this, let us consider the following situation. In two databases, distances between buildings of some company are stored. In the first database, it is given that the distance between buildings *A* and *B* is equal to 5.5 miles, while in the second database, the same distance is presented as 5½ miles. We see that data are different (5.5 and 5½) but the information is the same. Another example of inadequacy is when we represent the same distance in miles and kilometers. For someone who knows how to convert miles in kilometers and vice versa, information will be the same although data representing this information are different.

The distinct nature of data and information has been emphasized by different researchers. For instance, Pérez-Montoro [Pérez-Montoro, 2007] treats data as physical events (small parts (or pieces) of reality) able to carry certain associated information, *i.e.*, data are physical supports or carriers of information. If there are, and there will always be, remaining epistemic as well as ontological properties to be ascribed to information, in LIR, they can co-exist and interact with ontological ones without conflation.

5.2 Semiotic Theories

At first sight, the semiotic approach to information might appear to capture its multiple facets, ordering them into the functional categories proposed by C. S. Peirce. Brier [Brier, 2008] has provided an informational interpretation of Peirce.

However, we consider Peirce's theory insufficiently dynamic because there is no energy that can be assigned to his triadic relations that would give them a basis in reality (physics). The same problem arises with Peirce's categories as with the Hegelian triad of thesis, antithesis and synthesis: there is no deductive basis for the movement from one term to the other or a description of any physical interaction between them. If the argument is made that nothing of the sort is required, then this may be exactly the problem – the terms are not physically grounded and hence have limited explanatory value other than as a heuristic device for keeping track of the entities involved in biological processes; its use should not make one neglect the real properties of the system.

The Peircean semiotic concept of information has been developed by Quieroz, Emmeche and El-Hani (the QEE approach) as a "triadic dependent" process where a form is communicated from an Object to an Interpretant through the mediation of a Sign [Quieroz *et al*, 2008]. At the same time, as stated by Peirce himself, it is derived from a *formal* science of signs that provides an *analytical* framework. Thus the QEE approach to information as process is constrained by the abstract characteristics of the Peircean categories, that is, their abstraction from dynamic aspects of real physical phenomena.

In contrast to the QEE approach, it is possible to derive the triadic characteristics from the LIR view of the contradictorial evolution of all real processes, providing the physical basis for the QEE differentiation of potential and effective (actual) semiosis and consequent definition of potential and effective *information* as well. In LIR, information is a complex of processual interactions with both binary (dyadic) and ternary (triadic) properties, all of which can be predominantly actualized (effective) or potentialized (not effective) at any time. This would seem preferable to the nebulous concept of a Sign as a Medium for communication of Form.

The essentially static linguistic definition of Form in terms of "conditional propositions" states that certain things would happen under certain circumstances. Strikingly, as quoted by Quieroz, et al, Peirce said that "*Form can also be defined as potentiality* (*'real potential': EP 2.388*). In LIR, structure and form are also physical processes, including the physical processes of their conceptualizations. Form is characterized not as 'potential' only, but as a process whose elements are both actual and potential at the same time.

LIR confirms the QEE approach to the argument by Jablonka that "for a source to be an information input rather than merely a source of energy or material, its *form*, or variations in its form, rather than any other attribute should affect the interpreter's response in a consistent, regular way". Here, a distinction has been created according to which form is idealized as something non-energetic, but still with causal properties. Conceptualizing form as a structure [Burgin, 2010], we see that the main operands of information operators are structures and information itself as a constituent of the World of Structures [Burgin, 2010]. A similar result is obtained by looking at both form and structure as active processes [Brenner, 2008]

5.3 Enformation

In the late 1980's, John Collier [Collier, 1990] introduced the term *enformation* as It is called intrinsic information or *enformation* which basically describes the ability of a system to be what it is, measuring the structural constraints internal to the system. These structural constraints have a potential to change the system of knowledge and thus, we can see that enformation is a type of the cognitive information in the sense of the General Theory of Information. If intropy (the inverse of entropy) represents the energetic aspect of causal power, enformation is the ability to alter the structure of things representing the organizational aspect of causation, as well as the ability to guide energy to do work. Without going into the details here, we note Collier's view that there is a close theoretical relation between intropy and enformation and that there is a "common property" of which they are different forms.

Several questions remain open in this approach, for example, how "raw" information is transformed into cognitive and biological content and form, in other words, how the information in a natural law can be transmitted. Collier: "It seems that an inference beyond the available information is always required." Logic in Reality talks to both of these issues, in its inclusion of potentialities in "raw" information that provide the causal power for the transformation and a principled manner of making inferences. Thus, LIR provides the basis for distinguishing between enformation and stored information, only the former having higher-level dynamic, albeit potentialized properties If, in addition, we see even raw, intrinsic information as an operator, with causal power, a coherent theory relating energy and information begins to appear.

In our view, the concept of enformation has received insufficient discussion in the interim although it represents valid and original insights. This concept is intrinsically compatible with our approach to seeing information-as-operators, giving more evidence for our cognitive perspective.

5.4 The Philosophy and Metaphilosophy of Information

Metaphilosophical approaches to information that emphasize its causal, pragmatic aspects, such as the Basic Theory of the Philosophy of Information of Wu Kun [Wu, 2010], are fully compatible with our conception of information as a natural and/or social operator. In fact, Wu insists on the central role of natural and social information and/or informational processing operations throughout in defining, ontologically, existential significance and value. We simply suggest that, depending on the objective of the analysis, one may focus on either the "partners" of operator and operand or on operations-as-processes.

It is interesting to note that Logic in Reality 1) also provides logical support to the original phenomenological concepts of Wu; 2) suggests an grounding of information in a non-Cartesian dualism that brackets outstanding issues in quantum physics; and 3) provides a further description of informational interactions, activities and values and their evolution. [Brenner, 2011] shows the synergy between the two approaches that defines a Metaphilosophy of and a Metalogic for Information. Wu’s concept of Informational Thinking amounts to *informational stance*, a philosophical stance that is most appropriate for, and above all not separated nor isolated from, the emerging science and philosophy of information itself.

One of our major conclusions is thus that the BTPI of Wu and its formulation as a metaphilosophy constitute a major contribution, as yet unrecognized outside China, to the General Theory of Information that is the subject of this Conference. This approach is discussed in another paper by one of us (Brenner) presented at this Conference.

Conclusion

The concept of information as operators is proposed in this paper as a contribution to the discussion of the general properties of information. It is not intended as a complete general theory of information, but it is compatible with theories that emphasize the ontological, causal powers of information processes. The key distinction between symbolic and natural operators, in our view, is that natural operators participate in interactive, dialectical relations with their operands, and that these interactions follow the patterns of evolution described by Brenner’s Logic in Reality. In cognition, for example, the key individual natural operator is the human mind or psyche, and groups of individuals function as operators at the social level of reality.

Progress in the construction of a more comprehensive General Information Theory in which, as Brier envisions, different theories would co-exist and support one another will require taking into account the complex transdisciplinary properties of information that are characteristic of all natural processes. Logic in Reality (LIR) provides a new logical or metalogical, transdisciplinary framework for the discussion of philosophy in relation to information, and we have come to the conclusion that the concomitant use of LIR, together with Burgin’s General Information Theory to describe information and its operation in society is unavoidable.

Our intention is to develop the concept of information-as-operators in both theoretical and practical directions. Our approach, which uses the tools of Burgin’s General Information Theory and Logic in Reality, can be also applied to the categorization of the various types of symbolic operators - mathematical, logical and linguistic - which we as noted are derivable from natural operators. In particular, we will address the issue of symbolic operators in Information Technology and Computer Science which are extremely important in the evolving Information Society.

Bibliography

[Bar-Hillel and Carnap, 1952] Y. Bar-Hillel and R. Carnap. An Outline of a Theory of Semantic Information, Technical Report No. 247, Research Laboratory of Electronics, MIT, Cambridge, Mass. In: Language and Information. Ed. Y. Bar-Hillel. Addison-Wesley, Reading, Mass., 221–274.

[Bar-Hillel and Carnap, 1958] Y. Bar-Hillel. and R. Carnap. Semantic Information. British J. of Philosophical Sciences 4(3):147-157.

[Barinaga and Ramfelt, 2004] E. Barinaga and L. Ramfelt. Kista – The Two Sides of the Network Society. In: Networks and Communications Studies, 18 (3-4):225 – 244.

[Bekenstein, 2003] J. D. Bekenstein. Information in the holographic universe. Scientific American 289(2):58-65.

[Brenner, 2005] J. E. Brenner. Process in Reality: A Logical Offering. Logic and Logical Philosophy 14:165-189.

[Brenner, 2008] J. E. Brenner. Logic in Reality. Springer, Dordrecht.

[Brenner, 2010] J. E. Brenner. Information in Reality: Logic and Metaphysics. Paper, 4th International Conference on the Foundations of Information Science, Beijing, August, 2010.

[Brenner 2010a] J. E. Brenner. The Logic of Ethical Information. In: Knowledge, Technology, Policy. Ed. H. Demir, 23(1-2), 109-133.

[Brenner, 2011] J. E. Brenner. Wu Kun and the Metaphilosophy of Information. Paper, IXth International Conference, General Information Theory, Varna, June 20 – 26.

[Brier, 2008] S. Brier. Cybersemiotics. Why Information is not enough. University of Toronto Press, Toronto.

[Burgin and Simon, 2001] M. Burgin and I. Simon. Information, Energy, and Evolution. Preprint in Biology 2359, Cogprints, (electronic edition: http://cogprints.ecs.soton.ac.uk).

[Burgin, 2010] M. Burgin. Theory of Information: Fundamentality, Diversity and Unification. World Scientific, New York/London/Singapore.

[Carnap, 1950] R. Carnap. Logical Foundations for Probability. University of Chicago Press, Chicago.

[Castells, 2000] M. Castells. The Information Age: Economy, Society and Culture. Volume I The Rise of the Network Society (2nd Ed.). Blackwell Publishing, Malden-Oxford-Carlton.

[Collier, 1990] J. D. Collier. Intrinsic Information. In: Information, Language and Cognition. Ed. P. Hanson. Vol. 1. Vancouver, University of British Columbia Press (now Oxford University Press).

[Crutchfield, 1990] J. P. Crutchfield. Information and its Metric. In: Nonlinear structures in Physical Systems – Pattern Formation, Chaos and Waves. Springer-Verlag, New York.

[Csanyi, 1989] V. Csanyi. Evolutionary Systems and Society. Duke University Press, Durham/London.

[Floridi, 2004] L. Floridi. Open Problems in the Philosophy of Information. Metaphilosophy 35(4): 554-582.

[Ghils, 1994] P. Ghils. Les tensions du langage. Peter Lang, Berne/Berlin

[Hintikka, 1968] J. Hintikka. The Varieties of Information and Scientific Explanation. In: Logic, Methodology and Philosophy of Science. Eds. B. van Rootselaar and J. F. Staal. Amsterdam, III, 311-331.

[Hintikka, 1970] J. Hintikka. Surface Information and Depth Information. In: Information and Inference, Synthese Library, Humanities Press, New York, pp. 263-97.

[Hintikka, 1971] J. Hintikka. On Defining Information. Ajatus 33:271–273.

[Kampis, 2002] G. Kampis. A Causal Model of Evolution. http://www.jaist.ac.jp/~g- kampis/SEAL02/A_Causal_Model_of_Evolution.htm.

[Kaye, 1995] D. Kaye. The Nature of Information. Library Review 44(8):37–48.

[Landauer, 2002] R. Landauer. Information is Inevitably Physical. In: Feynmann and Computation: Exploring the limits of Computers. Westview Press, Oxford, pp. 76-92.

[Leydesdorff, 2006] L. Leydesdorff. The Knowledge-Based Economy: Modeled, Measured, Simulated. Universal Publishers, Boca Raton, Florida, 2006.

[Leydesdorff, 2010] L. Leydesdorff. Redundancy in Systems which Entertain a Model of Themselves: Interaction Information and the Self-organization of Anticipation. ENTROPY 12:63-79.

[Loewenstein, 1999] W. R. Loewenstein. The Touchstone of Life: Molecular Information, Cell Communication, and the Foundation of Life. Oxford University Press, Oxford/New York.

[Lupasco, 1973] S. Lupasco. Du devenir logique et de l'affectivité; Vol. 1: Le dualisme antagoniste. Essai d'une nouvelle théorie de la connaissance. J. Vrin, Paris. (Originally published by J. Vrin, Paris,1935).

[Magnani, 2002 L. Magnani. Preface to Model Based Reasoning. In: Magnani L, Nersessian NJ (eds) Science, Technology, Values. Kluwer, Dordrecht.

[Pérez-Montoro, 2007] M. Pérez-Montoro. The Phenomenon of Information: A Conceptual Approach to Information Flow. The Scarecrow Press, Medford, N.J.

[Prigogine, 1980] I. Prigogine. From Being to Becoming: Time and Complexity in Physical Systems. Freeman & Co., San Francisco.

[Quieroz et al., 2008] J. Quieroz, C. Emmeche and C. N. El-Hani. A Peircean Approach to 'Information' and its Relationship with Bateson's and Jablonka's Ideas. The American Journal of Semiotics. 24 (1-3): 75-94.

[Reading, 2006] A. Reading. The Biological Nature of Meaningful Information. Biological Theory 1(3):243-249.

[Scarrott, 1989] G. G. Scarrott. The Nature of Information. Computer Journal 32(3):262-266.

[Seibt, 2009] J. Seibt. Forms of Emergent Interaction in General Process Theory. SYNTHESE 166:479-512.

[Sequoiah-Grayson, 2007] S. Sequoiah-Grayson. The Metaphilosophy of Information. Minds & Machines 17:331-334.

[Shreider, 1965] Y. A. Shreider. On the Semantic Characteristics of Information, Information Storage and Retrieval, Vol. 2, pp. 221-233 (in Russian).

[Shreider, 1967] Y. A. Shreider. On Semantic Aspects of Information Theory, Information and Cybernetics. Moscow, Radio, pp. 15-47 (in Russian).

[Smith and Szathmary, 1999] J. M. Smith and E. Szathmary The Origins of Life: From the Birth of Life to the Origin of Language. Oxford University Press, Oxford.

[Smolin, 1999] L. Smolin. The Life of the Cosmos. Oxford University Press, Oxford/ New York.

[Stonier, 1991] T. Stonier. Towards a new theory of information. Journal of Information Science 17:257-263.

[Thompson, 1968] F. Thompson. The organization is the information. Am. Document 19:305–308.

[Wheeler, 1990] J. A. Wheeler. Information, Physics, Quantum: The Search for Links. In: Complexity, Entropy, and the Physics of Information. Ed. E. Zurek. Addison-Wesley, Redwood City, California, 3–28.

[Wu, 2010] K. Wu. The Basic Theory of Philosophy of Information. Paper, 4-th International Conference on the Foundations of Information Science, August, 2010, Beijing.

Authors' Information

Joseph E. Brenner *-International Center for Transdisciplinary Research, Paris.*
P. O. Box: 235, Les Diablerets-1865, Switzerland; e-mail: brenner52@sbcglobal.net
Major Fields of Scientific Research: Logic, philosophy, epistemology

Mark Burgin *– UCLA, Information Editor-in-Chief, Department of Mathematics, UCLA, 405 Hilgard Ave, Los Angeles, California 90095, USA*
Major Fields of Scientific Research: Mathematics, information