Natural Operators, Social Operators and Symbolic Operators

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Abstract

Operators, as both conceptual and physical entities, are found throughout the world as a common feature of human mind, nature and society. As a reflection, operators are the basic tool in physics, quantum chemistry and genetics, playing an important role in other sciences. Operators, and what they operate, their substrates, targets or operands, have a wide variety of forms, functions and properties. We systematize and study operators which range from the most abstract formal structures and symbols in mathematics and standard logic to real entities, human and non-human, and are responsible for effecting changes at both the individual and social level. The emphasis of this paper is on the analysis and characterization of relations between natural operators and operators in science. This allows us to explain the success of the operator approach in physics.

By focusing on the nature and properties of operators in science and technology, we also acquire a possibility to achieve a more rigorous logical discussion of cognitive processes in the knowledge-centered information society. In this paper, we build an extensive classification of operators, demonstrate abundance of natural operators, explain how information operates in nature, analyze operators as a theoretical tool and describe to what extent a machine can be an operator. Studying self-operation, we explicate common features of several important phenomena, such as self-organization, self-regulation and self-management. Among our conclusions, we conjecture that the natural-social operator split provides a key criterion for determining what entities may be considered autonomous, morally responsible agents.

Keywords: operator, science, nature, transformation, logic, machine

1. INTRODUCTION. OPERATORS AND CHANGE

Many significant concepts in philosophy and science have proven extremely resistant to systematic explanation. Examples are *change*, *consciousness*, *information* and *intelligence*. At the same time, improved understanding of these concepts is of increasing importance for a more satisfactory theory of the contemporary Information Society aimed at efficient support of responsible attitudes toward economic growth and sustainable environment. Some of the problems with the above concepts can be addressed using process methodology or interactivist approach (Bickhard, 2009). Theories of information that emphasize both qualitative and quantitative properties of information and provide efficient means for solving problems of the contemporary Information Society have been also recently created (Burgin 2010). Conceptual understanding is additionally provided by the research focused on the inter- or trans-disciplinary aspects of concepts (Nicolescu, 2002), as well as on the combination of concepts from neuro-science and philosophy (Bennett and Hacker, 2003).

An additional general notion that has received little rigorous attention, and yet has implications throughout the whole reality is that of an *operator*. To our knowledge, no comparative study of operators and their substrates or operands in different areas, including society, has been made. Compartimentalized formalized concept definitions of operators are used in mathematics, logic, programming languages, and linguistics, while in everyday language, informal notions refer to familiar activities in the domains of machines, medicine, organizations and social activity.

However, this 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 unified theory of operators. In this paper, we develop in some detail the notion of such "*natural*" operators. We 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 abound in nature, mind and society.

The major objective of this paper is, accordingly, to provide a comprehensive classification and study of natural operators and operations in several practical and theoretical areas of current interest, including a new kind of logic called a *Logic in Reality* (LIR) (Brenner 2008). This logic is an extension of logic from symbolic structures to real, complex processes. Operators in this "natural" logic are considered as active processes involved in effecting change at biological, mental and social levels of reality. As we will show, the system of operators in this natural *logic in reality* constitute, therefore, a *logic of* natural *operators*. Our grounding of their properties in physics further supports the utility of natural operators in general and their usefulness for information technology in particular.

The development of the concept of natural operators in this paper, moving from science, information and non-standard process logic to humans as individuals, groups and society as a whole, thus provides a basis for some tentative conclusions about the roles of operators in a knowledge-based Information Society. In particular, we propose that the natural-social operator split provides a key criterion for determining what entities may be considered autonomous, morally responsible agents and thus, contributing to a solution of the principal-agent problem (agency dilemma), which is urgent for political science, sociology and economics.

The next Section 2 contains basic definitions of operators, specifying basic classes of operators and their properties and providing a conceptual framework for the remainder of this study. Section 3 defines and studies natural operators, including information as a natural operator and natural operators of logic in reality, explicating their relations to epistemology, causality, and philosophy of mind. In Section 4, we describe and analyze operators in science, making the emphasis on physics and biology. In Section 5, we study machine operators. Self-operation and self-operators are explored in Section 6, including operators of self-organization, self-regulation and self-management. Section 7 presents our conclusions addressing prospective work in both theoretical and practical directions in the areas of symbolic and social operators, respectively.

2. BASIC DEFINITIONS AND CLASSIFICATIONS: FUNCTION AND TYPE OF OPERATORS

Absence of a comprehensive discussion of operators has been due in part to the complexity of their differences in kind. The categorization we propose takes into account most if not all types of different operators, starting from a basic definition **O1**, which identifies the most general concept of an operator. It allows us to categorize all existing operators by their essential characteristics. However, the obtained categories are not independent. In fact, their key categorial feature is their Non-Separability, for which LIR provides a logical basis.

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

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

These definitions show that 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.

Definitions O1 and O2 express the fundamental dyadic relation which is actualized in the form of the operator triad:

$$\textbf{Operator} \xrightarrow{\text{Operation}} \textbf{Operand} \qquad (1)$$

Symbolic and natural operators function in a variety of areas: linguistic operators operate languages; 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 developed 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:

Definition OF1: A *symbolic operator* is an operator that has a symbolic form.

Definition OF2: A *material operator* is an operator that has a material form.

Definition OF3: A *mental operator* is an operator that is a part (element) of mentality.

Medium-oriented Classification:

Definition OM1: A *social operator* is an operator that works (functions) in society.

Definition OM2: A *nature operator* is an operator that works (functions) in nature.

Definition OM3: A *technology operator* is an operator that works (functions) in artificial world created by people, which includes technology and has been created by technology.

Target-oriented Classification:

Definition OT1: A *socialized operator* is an operator that works with/on social structures.

Definition OT2: A *symbolized operator* is an operator that works with/on symbols (symbolic structures).

Definition OT3: A *naturalized operator* is an operator that works/on with natural objects (systems).

Note that it is possible that an operator has different medium and target types. For instance, a social operator can and often does 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 acquires roles of a social and nature operator.

At a second level of classification, the basic parameters are *dynamics, origin* (*emergence*), and *function.*

Dynamic Classification:

Definition OD1: A *system operator* is a system that has both a static and dynamic structures or/and operates systems.

Definition OD2: A *function operator* is a function or/and an operator that operates functions.

Definition OD3: A *process operator* is a process or/and an operator that operates processes.

Existential Classification:

Definition OE1: A *natural operator* is a natural object, i.e., an object that emerged in nature and functions as an operator.

Definition OE2: A *artificial operator* is an artificial object, i.e., an object that is created by people or other living beings and functions as an operator.

Definition OE3: A *hybrid operator* is partially natural and partially artificial.

Function-oriented Classification:

Definition OG1: A *cognitive operator* is an operator the goal of which is knowledge acquisition.

Definition OG2: A *search operator* is an operator the goal of which is finding some object or information.

Definition OG3: A *construction operator* is an operator the goal of which is building some system.

2.1. Properties of Operators

For a study of individual human and non-human operators and their comparison with others, it is useful to take into account a number of important quantitative and qualitative properties in addition to their basic classifications. The set of considered here properties is a selection from the total set of transdisciplinary properties characteristic of natural processes and thus, it is not intended to provide a complete scientific description of operators. These properties serve simply to highlight our view that there are general principles applicable to the entire category of operators.

For convenience, we have separated these properties into three rough sub-categories, as follows:

- Intrinsic Properties

- *Complexity*
- *Power* reflects what the operator can do
- *Capabilities* reflect what means of action are accessible (used) by the operator

- Relational Properties

- *Relation* to the operated system (operand)
- *Attitude* to the operated system (for human operators)
- *Conditions and Restrictions* on operation

- Pragmatic Properties

- *Tentative (theoretical) costs* of operation (individual *human cost*, *moral cost* and *reputation cost*)
- *Actual results (benefits, profit)* from operation
- *Productivity*

This overall approach establishes that operators are characterized by their single or multiple classificatory definitions and their properties. For example, human beings are *material*, *natural*, *naturalized* and *socialized* operators. When reference is made to one of these definitions in the text, it will be in the bold italicized font, as here.

The indicated intrinsic, relational and pragmatic properties, which can be studied by the relevant disciplinary methodology, further characterize operators. In the remainder of the overview of our approach in this paper, however, we have limited the discussion of the sets of properties to a few key examples.

3. NATURAL OPERATORS

3.1 The Ubiquity of *Natural* Operators

The original concept of an *operator*, such as the differential operators d/dx, $\partial/\partial x$, $\partial/\partial y$, and $\partial/\partial z$, Laplacian L, and Hamiltonian H, has been one of the most efficient and developed tools of theoretical physics. Even the basic arithmetic operations, such as + and

–, are also operators as it has become clear with the advent of computer programming. Such symbolic, mostly mathematical, operators represent (describe) *natural* operators that are studied by physics and describe physical concepts, reflecting their properties. For instance, mathematical operators are used as models of the term *observable*, which has become the standard concept in quantum mechanics as the counterpart of the term *physical quantity* or *measurable quantity* in classical physics. This term originated from the term *observable quantity* (*beobachtbare Grösse*) defined by Heisenberg in his groundbreaking work on matrix mechanics (Heisenberg 1925). His goal was to specify physical quantities by means of an operational definition. As a result, in contemporary quantum mechanics, the observables of a physical system are represented by self-adjoint operators acting in the Hilbert space *H* associated with the system.

In general, an observable is a physical object or a property of such an object that some system (in a more restricted sense, people) can observe and/or measure. Thus, in the later development of quantum theory, several authors suggested the generalized representation of observables as positive operator measures (Ludwig, 1964; Davies and Lewis 1970; Kraus 1983). This concept advanced the mathematical coherence and conceptual clarity of the quantum theory. From physics, mathematical operators were extended to quantum chemistry where they also have been successfully used to model different processes.

However, taking the definition **OE1** of a ***natural*** operator (cf. Section 2), we see that the entire real world is full of operators. In essence, any physical or biological object or system that interacts with and impacts other physical and/or biological objects or systems is a ***natural*** operator. Indeed, it is hard to find a system in nature that is not interacting with its environment. Thus, a system *A*, which interacts with a system *B*, as a rule, has some impact on the system *B* – either the state of *B* is changed or functioning/behavior of *B* is changed or the whole system *B* is changed. Consequently, according to Definition **O1**, the system *A* is a ***natural*** operator, while according to Definition **O2**, the system *B* is a ***natural*** operand. The multitude of ***natural*** operators is studied by natural sciences. As a result, ***natural*** sciences could be called a study of operators!

From this perspective, the notion of operator and operand has a relation to the critical philosophical concept of causality. If the role of efficient cause can be ascribed to an operator, it is not easy to define the apparently passive role of operand using standard logic and causality theory.

3.2 Information as a Natural Operator

In the general theory of information, 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* (cf. Definitions **OM2** and **OM3**), which acts on different systems. Thus, it is reasonable to distinguish *potentialized and actualized* components of information, whose evolution follows the pattern of Logic in Reality, as discussed in Section 3.3.

3.2.1 DNA as Information

Information present in ***natural*** objects is a ***natural*** operator. A well-known example of such information is genetic information stored in DNA. Genetic information is stored in the linear sequence of nucleotides in DNA (deoxyribonucleic acid) and written as text in the alphabet of three base pair sequences (tri-nucleotides) called *codons*, while the *genome* is the entirety of an organism's hereditary information (Sinden 1994). Usually, the term *genome* means genetic information stored on a complete set of nuclear DNA. Sometimes this term is also applied to genetic information stored within DNA of organelles. To discern these cases biologists use such terms as the *nuclear genome*, *mitochondrial genome* and *chloroplast genome*. DNA of the human genome is arranged into 24 distinct *chromosomes* - physically separate molecules. Each chromosome contains many *genes*, the basic physical and functional units of heredity. Genes are specific sequences of bases that encode instructions on how to make proteins. Thus, genomes are examples of information as ***natural*** operators.

In his book “The Touchstone of Life" (1999), Loewenstein 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.

3.2.2 Energy as Information

Energy is an example of information in a broad sense (Burgin 2010) - **Ontological Principle O2**, and thus the most basic ***natural*** operator. According to Smolin (1999), the three-dimensional energetic world is the flow of information. In a similar way Stonier (1991) asserts, structural and kinetic information is an intrinsic component of the universe, independently of whether any form of intelligence can perceive it or not. Reflecting this approach, Bekenstein (2003) claims that there is a growing trend in physics to define the physical world as being made of information itself. From this point of view, ***natural*** information operators are present in all ***natural*** systems. Even more radical point of view is expressed by Wheeler (1990), who claims that every item of the physical world is information-theoretic in origin. In this view, all such information is composed of a multitude of information operators, *e.g.*, information in an instruction is an information operator, a *system* or *function* operator (**OD1** or **OD2**). 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 idealizations of the concept of information that make Plato's conceptions look realist.

We know that the common usage of the word information does not imply such wide generalizations as the Ontological Principle O2 implies. Thus, we need a more restricted theoretical meaning because an adequate theory, whether of information or of anything else, should correspond to our commonsense notions of its content.

3.2.3 Infological Systems

Information in the strict sense is defined as constituted by and acting upon structural subsystems which we designate as its infological system. For example, systems of knowledge are infological systems. For precision in this information definition, we make two conceptual steps. First, we make the concept of information relative to the chosen infological system IF(*R*) of the system *R* and then we select a specific class of infological systems to specify information in the strict sense.

An infological system plays the role of a free parameter in the general theory of information, providing for representation of different kinds and types of information in this theory. That is why the concept of *infological system*, in general, should not be limited by boundaries of exact definitions. A free parameter must really be free. Identifying an infological system IF(*R*) of a system *R*, we can define information relative to this system. This definition is expressed in the following further **Ontological Principle O2g** (**the *Relativized Transformation Principle***). *Information* for a system *R relative to the infological system* IF(*R*) is a capacity to cause changes in the system IF(*R*), that to operate upon it.

As a model example of an infological system IF(*R*) of an intelligent system *R*, we take the system of knowledge of *R*. It is called in cybernetics the *thesaurus* Th(*R*) of the system *R*. Another example of an infological system is the memory of a computer. Such a memory is a place in which data and programs are stored and is a complex system of diverse components and processes.

Elements from IF(*R*) are called *infological elements*. There is no exact definition of infological elements although there are various entities that are considered as infological elements as they allow one to build theories of information that include conventional meanings of the word *information*. For instance, knowledge, data, images, ideas, algorithms, procedures, scenarios, schemas, values, goals, ideals, fantasies, abstractions, beliefs, and similar objects are standard examples of infological elements. The understanding of this approach is facilitated by also seeing these elements and processes and *logical* in the sense of Logic in Reality (cf. Section 3.3 below)

These ideas are crystallized in the following principle: **Ontological Principle O2a** (**the *Special Transformation Principle***). *Information in the strict sense* or *proper* *information* or, simply, *information* for a system *R*, is a capacity to change structural infological elements from an infological system IF(*R*) of the system *R*. To better understand how infological systems can help to explicate the concept of information in the strict sense, we consider cognitive infological systems.

An infological system IF(*R*) of the system *R* is called *cognitive* if IF(*R*) contains (stores) elements or constituents of cognition, such as knowledge, data, ideas, fantasies, abstractions, beliefs, etc. A cognitive infological system of a system *R* is denoted by CIF(*R*) and is related to cognitive information. In this case, it seems possible to give an exact definition of a cognitive infological system. However, current cognitive sciences do not capture all the structural elements involved in cognition. A straightforward definition specifies cognition as an activity (process) that gives knowledge. At the same time, we know that knowledge, as a rule, comes through data and with data. So, data are also involved in cognition and thus, have to be included in cognitive infological systems. Besides, cognitive processes utilize such structures as ideas, algorithms, procedures, scenarios, images, beliefs, values, measures, problems, tasks, etc. Thus, to comprehensively represent cognitive information, it is imperative to include all such objects in cognitive infological systems. Further discussion of infological systems is provided in (Burgin 2010).

3.2.4 Further Aspects

Some of the further 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 (1968) asserts that "the organization is the information", and 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 (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.

Information plays an important role in evolution, as in the elegant theory of evolution developed by Csanyi (1989) and Kampis (1991). 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 (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 as **a *natural* operator.**

The issue of the 'physicality' of information is the subject of intensive on-going debate (information as a "physical essence"). Crutchfield (1990) treats information as "the primary physical entity from which probabilities can be derived." 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 (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.

We now come to another portrayal of *natural* operators, including informational ones, that emerges from the extension of formal logic to real systems that has been made by Brenner (2008). As we will see, the LIR logical system moves the discussion of operators from the primarily theoretical domain toward operational characteristics of the human mind and human individual in society.

3.3 Natural Process Operators of Logic in Reality (LIR)

Logic is often defined as the theory of correct reasoning, where logic is understood as classical bivalent propositional and predicate logics or their modern multivalent, fuzzy, epistemic, temporal, modal, deontic or intuitionist versions (Jacquette, 2007). Such logics are neither intended to describe nor have the capability of describing reality in nature or society. The applicability of logic and its symbolic operators and operations has been limited to language and mathematics. This is, however, based on a discretionary metalogical principle introduced by the scholastic followers of Aristotle and maintained by the linguistic turn of the 19th – 20th centuries.

Writing in the middle of the last century, the Franco-Romanian philosopher Stéphane Lupasco challenged the monolithic propositional, truth-functional character of logic and proposed an extension of logic to real process phenomena, based on the perceived dualities of matter-energy. In this new (old) way of "doing" logic, Lupasco essentially carried out a metalogical rejunction of logic with its original function as natural science (Brenner 2010b).

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. 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 2010b).

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 (Brenner 2008). 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).

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.

The *function* (Definition **OD2**) and *process* (Definition **OD3**) 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 (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 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.

3.4 Causality

The discussion of the nature of operators allows us to explicate their relations to the notion of causality or cause and effect. It is easy to accept that all operators are efficient causes, but are all causes operators? Further, what is the causal nature of the operator-operand interaction?

The key conceptions in standard theories are those of Prigogine of dissipative systems far from equilibrium, continued by Salthe among many others. “The thermodynamic view focuses upon a final causality that operates universally. A functional separation is maintained between cause and effect, reifying them as entities separate from the property-processes they are supposed to operate on. For example, the intervention I must completely change any causal relationships between X and *its* prior causes. Nevertheless, one comment of Woodward (2001) suggests some underlying common intuition. He suggests that philosophers do tend to think of causes as properties or events, but that it is possible to move back and forth between such talk and a representation in terms of variables. When there is no well-defined notion of change or variation in value, almost any standard theory, *e.g.*, of manipulability, will not see genuine cause, but some form of epiphenomenality.

LIR defines values of actualization and potentialization as applying not only to causes-as-events, but also to the ‘moving back and forth’, the epistemological shift, also considered as a physical, dynamic process. A domain in which there is no well-defined notion of change is likely to be, in LIR, one in which the only connection is absolute disjunction, and where, to all intents and purposes, a binary logic is adequate.

By localizing the origin of action in the *potential aspects* of phenomenal processes, which in the LIR view are intrinsic properties of all operators, our approach cuts through the debate on whether causation by omission, absence and prevention are cases of causation or not. They are. This line of argument also applies to the artificial distinction between natural and causal change, as well as internal and external change. LIR thus supports and explicates Fair’s transference theory according to which, as discussed by Dowe (2008), causation is a transfer of energy and/or momentum although causation by absence does not include any transfer of energy or momentum. Besides, in the context of the general theory of information, causation necessarily is a transfer of information (Burgin 2010). This brings us to the concept of relative causation dependent on the observer.

Further detailed discussion of the subject of causality, (which has been called the “black hole” of philosophy), is beyond the scope of this paper. We believe that the major source of difficulties with standard views of the energetic aspects of cause, and the relation between cause and effect, have been due to the use of the conventional mutually exclusive categories of standard logic and category theory. In real complex situations, the reciprocal relations of feedback from operand to operator are of equivalent importance to the original *relational* property. Any human operator where the operation involves intentionality, operating as a cause, will be accompanied by a minority contradictorial tendency either *not* to operate or to cause the *opposite* effect. Logic in Reality permits a formalization of the parallel chains of causality (Brenner 2008). Operation and cause are, accordingly, equivalent descriptions the choice of which will be defined by the specific focus of the subject of analysis.

3.5 Mind and Knowing: *Psyche* as a Natural Operator

Most of the difficulties in the vast variety of theories of mind and knowledge have been in finding the essence of "what it is" to be an entity with conscious awareness and causal efficacy. The concept of natural operators as a description of the operation of the LIR principle of dynamic opposition provides access to a new epistemology in which the classical entities of knower, knowing and known (knowledge) are all seen as processes in dialectic or contradictorial interaction.

In this Section, we are concerned with both individual mental processes and their totality, exposing their nature as operators, and choosing the term *psyche* (the Greek word for mind and soul) following Jung who used it for this totality. There is a striking similarity between his foundational view of opposition as an inherent principle of human nature (Jung 1971) and dynamic opposition in LIR. As Jung wrote, "A psychological theory, if it is to be more than a technical makeshift, must base itself on the principle of opposition. … There is no balance, no system of self-regulation, without opposition. The psyche is just such a self-regulating system." Jung described the forces at work in terms of energies in language that is easy to compare with the LIR grounding in energy, and the *need* for opposition is clear from his emphasis that "there is no energy unless there is a tension of opposites".

We first note that members of *all* classifications of operators are instantiated in the psyche, providing a kind of rough measure of its existence as the most complex, natural object in the universe. To the suggestion that society, as an entity composed of multiple minds, is more complex, our answer is that many of the individual operations of society are less complex, involving fewer types of operators. Society as a collective entity or system (or 'being' in the sense of Minati and Pessa (2006) instantiates emergent simplicity. In addition, the *psyche* is one of the basic concepts of depth psychology, comprising the forces in an individual that influence thought, behavior and the whole personality.

Freud described the structure of the psyche as composed of three components:

- The *Id*, which represents the instinctual drives of an individual and functions mostly unconscious.

- The *Super-Ego*, which represents a person's implicit knowledge about social environment, including internalization of social norms, morality and other standards, functioning mostly unconscious.
- The *Ego*, which represents a person's conscience and serves to integrate the drives of the Id with the prohibitions of the Super-Ego.

In essence, Ego connects Id and Super-Ego, forming the following Fundamental Triad (Burgin 1993a; 1993b).

$$\textbf{Id} \xrightarrow{\quad\textbf{Ego}\quad} \textbf{Super-Ego} \qquad (2)$$

Thus, in this context, the psyche controls an individual's functioning, behavior and personality. Consequently, psyche is a ***natural*** operator, with a compound structure built up from other simpler operators, forming a sophisticated hierarchy. Our intention is not to argue here for the validity of this descriptive system but simply to provide an interpretation in our "operator" language.

It is important to note, however, that the diagrams and discussions of the Fundamental Triad in this paper are univocal, without reference to bi-univocal relations, recursion and feedback involving operator and operand. The structure of such interactions is critical for any reasonable models of the mind, memory and complex social phenomena such as the economy. For discussions of these aspects, the reader is referred to Lupasco (1986), Leydesdorff (2006) and Burgin (1993b).

3.6 From Perception to Cognition

To further apply logical operations as dynamic processes, outlined in the previous sub-Section, to the human mental system, we start by looking at the dialectics of afferent and efferent systems in perception. Prior to excitation – a *natural* physical/biological operator - by internal or external stimuli, we assume that the afferent system is in a state of potentiality, maintained by the antagonistic actualization of the polarization or electrostatic equilibrium. Excitation results in a new actualization, potentializing the ionic equilibrium, the reception of an equivalent to heterogeneity of sensations. The new equilibrium state of perception appears, in its homogeneity, as something objective, exterior, an identity of which one can have 'knowledge', while sensations, although really belonging to the external world, *appear* interior to the senses and more subjective. The dialectics established in and by the afferent process is between the conscious mind of (or as) the 'knower', actualizing a series of energetic heterogeneities, and the 'known' displaced to the exterior in the potentiality of energetic homogeneity. This conception could be called 'pan-energetics', but it is not a pan-psychism, the mind appears as an aspect of the structuring and operation of energy.

Following re-equilibration (re-polarization) of the excited nerve cells in a T-state, efferent stimuli leave the brain in the direction of organs of movement (of course with the possibility of many intermediate feedback loops), with a dialectics that is the inverse of the afferent system. Its actualization looks like a *plan*, an operator capable of active structural homogenization, which will be opposed by the heterogeneity of the external world in which it will operate, and the dialectics involve thus the imposition of this plan on the external world, and the potentialization of this heterogeneity. Thus, there is a dialectics of the contradictory and antagonistic dialectics of perception and action, which implies, since one does not exist without the other, that each succeeds the other, although neither is very far, in the nervous system, from the T-state.

The difference between actualizations that potentialize and potentializations that actualize is not continuous, and the pauses in the process, in the T-state, are what can be considered states of control. These constitute the dialectic of the psyche, which *becomes* what is generally called consciousness. There is thus in the LIR theory, no such 'consciousness of', no reification or objectification, only *that* which occupies the conscious mind, *that* which is potentiality itself, what is commonly called consciousness, with the capacity for causal change that justify its characterization as a *natural* operator.

3.7 Knower, Knowing and Known

The LIR approach to knowledge purposefully includes it in reality. For instance, knowledge in a biological organism originates in, and can never be totally separated from, the set of processes that constitute its existence, including an organism's systems of perception and action. All these processes instantiate both reciprocal degrees of actuality and potentiality and different tendencies toward identity and diversity. The objects subject to these systems relations are the knower and a knowable or a known, as well as the exterior and an interior reality. The essential hypothesis is that the knower does not and cannot know himself in the process of knowing insofar as he/she knows or is in a process of knowing. Using a Leibnizian argument, we can show that for knowledge to exist, the knowable and the known must be neither totally identical to nor totally different from the knower. This is similar to the fundamental *Dynamic Knowledge Triad*, an important case of the Fundamental Triad described by Burgin (1993a; 1993b), where the structure (4) is the actual form and the structure (5) is a potential form of the structure (3). In LIR, knower, knowing and known all instantiate both actuality and potentiality.

$$\text{Knower} \xrightarrow{\text{Knowing}} \text{Known/Knowable} \qquad (3)$$

$$\text{Knower} \xrightarrow{\text{Knowing}} \text{Known} \qquad (4)$$

$$\text{Knower} \xrightarrow{\text{Knowing}} \text{Knowable} \qquad (5)$$

We assume, following the fundamental postulate of LIR, that existence and non-existence and the knowable and known in which they manifest themselves are dualities with contradictory terms, for one to be (predominantly) actual, the other must be (predominantly) potential. Thus when we know or do something, we do not know (or pay attention to) our knowing of it. We can focus, by another cognitive act, on our knowing, which does not know itself as such, and so on.

The core of this theory is that we *know* only what is potential – what is conceptual and ‘ideal’, the inverse of that which is relegated to the unconscious and according to which we act. The actual is always impossible to know, due to the nature of knowing itself, a concept that corresponds to the general idea according to which one cannot act, contemplate, etc. and see oneself act, contemplate, etc. at the same time. The known is neither totally identical nor totally other than the knower. The dualities are contradictory as one of them is (mostly) actual, while the other must be (mostly) potential. Although the roles of these dualities are changing, the two are not both fully actual at once, but as one is primarily actualized, the other is primarily potentialized.

In the present theory, the known is an element or entity or process that is contrary and contradictory to the knower. Together, they constitute antagonistic dynamisms in which alternating actualization and potentialization converts known to knower and *vice versa.* A known becomes a knower since 'knowledge' is not the knowledge that a knower 'has' but is a *process* that is active in the knower. As a part of an individual's total mental structure, this process, in a non-metaphorical sense, 'knows' or becomes a knower and accordingly, like knowing itself, is a natural operator as a consequence of the dialectics of contradiction.

4. SCIENCE AS A STUDY OF NATURAL OPERATORS

Existence of variety of natural operators resulted in the operational approach in physics and operationalism in the methodology of science. Now the concept of *operator*, such as the differential operators d/dx, $\partial/\partial x$, $\partial/\partial y$, and $\partial/\partial z$, Laplacian L, and Hamiltonian H, is one of the most efficient popular and developed tools of theoretical physics. Thus, in physics, there are symbolic, mostly mathematical, operators, which represent (describe) natural operators studied by physics, as well as physical concepts reflecting properties of natural operators. For instance, mathematical operators are used as models of the term *observable*, which has become the standard concept in quantum mechanics being the counterpart of the term *physical quantity* or *measurable quantity* in classical physics. History of physics shows that this term originated from the term *observable quantity* (*beobachtbare Grösse*) by Werner Heisenberg in his groundbreaking work on matrix mechanics (Heisenberg, 1925). His goal was to specify physical quantities by means of an operational definition. As a result, in contemporary quantum mechanics, the observables of a physical system are represented by selfadjoint operators acting in the Hilbert space H associated with the system. In general, an observable is a physical object or a property of such an object that some system (in a more restricted sense, people) can observe and/or measure. Thus, in the later development of quantum theory, several authors suggested the generalized representation of observables as positive operator measures (e.g., (Ludwig, 1964; Davies and Lewis, 1970; Kraus, 1983). It has essentially advanced the mathematical coherence and conceptual clarity of the quantum theory.

From physics, mathematical operators came to quantum chemistry where they are successfully used to model different processes..

Measurement devices often are technological nature operators. As a rule, they operate physical system characteristics and parameters they measure. This peculiarity of measurements has found its reflection in operationalism as a constructive direction in the methodology of science. Operationalism developed by the American physicist Percy Williams Bridgman represents the view that all scientific concepts must be defined only in terms of procedures or operations by which they are measured or applied. This implies necessity of an operational semantics for scientific theories. In turn, the operational semantics brings us to operators because procedures are realized and operations performed by operators. In this context all measuring devices and all measurements are operators as they operate knowledge of researchers who use these devices. In turn, experimenters are operators with respect to measuring devices as they operate these devices.

Taking the definition of a natural operator from Section 2, we see that that the whole world is full of operators, i.e., of systems that interact and impact one another. This is also true for nature. Indeed, it is hard to find a system in nature that is not interacting. Thus, a system A, which interacts with a system B, as a rule, has some impact on the system B – either the state of B is changed or functioning/behavior of B is changed or the whole system B is changed. Consequently, according to Definition O1, the system A is a natural operator, while according to Definition O2, the system B is a natural operand.

There is a multitude of examples of natural operators and all these operators are studied by science. Here are some of them.

We start with such habitual physical systems as stars and planets.

The Sun is definitely an operator, which operates a variety of systems. The majority of plants can exist only because they get light that comes from the Sun. In photosynthesis, plants use sunlight energy to create usable chemical energy. In particular, the carbohydrates necessary for cell respiration are formed. Photosynthesis is a two stage process. The first stage is called the *light reaction*, since it is dependent on light in making energy carrier molecules that are used at the second stage. The second stage is called the *dark reaction*, since it has been considered light independent. However, recent studies suggest that the dark reaction is indirectly stimulated by light. Thus, light, which is usually coming from the Sun, plays the central role in plants life, enabling and controlling plant functioning. It means that the Sun operates the majority of plants.

In addition, to normally function, people, birds and animals need the light that comes from the Sun. For instance, functioning of people, birds and animals is organized in repeating cyclic patterns and these cycles depend on changes caused by the Sun radiation due to the Earth's rotation around its axis and around the Sun. One of the most important is the *circadian rhythm*, which is a roughly 24-hour cycle in the biochemical, physiological, or behavioural processes of living entities on Earth, including plants, animals, fungi and cyanobacteria. Although circadian rhythms are endogenous ("built-in", self-sustained), they are adjusted (entrained) to the environment by external cues, the primary one of which is daylight. In such a way, the Sun operates people, birds and animals.

Sunlight and consequently, the Sun also operate the *pineal gland* or *epiphysis*, which synthesizes and secretes melatonin, a structurally simple hormone that communicates information about environmental lighting to various parts of the human and animal body. Ultimately, melatonin has the ability to entrain biological rhythms and has important effects on reproductive function of people and many animals. The light-transducing ability of the pineal gland has led some to call the pineal the "third eye". Synthesis and secretion of melatonin is dramatically affected by light exposure to the eyes. The fundamental pattern observed is that serum concentrations of melatonin are low during the daylight hours, and increase to a peak during the dark.

The Sun too has a crucial impact on people's perception and orientation because people can see and orient themselves much better in the daylight. For instance, light that comes from the Sun allows people to better see and better figure out what they see..

Moreover, scientists found that different processes that go on the surface of the Sun can influence health of people. For instance, people can burn their skin if they are exposed to direct sunrays for a long time.

The great impact of the Sun on people and other living beings resulted in the fact that in many ancient societies the Sun was treated as a god. For instance, in ancient Egypt, *Ra*, also called *Ré*), is the ancient Egyptian sun god. To the Egyptians, the sun represented light, warmth, and growth. This made the sun deity very important, which was seen as the ruler of all that he created. The sun disk was either seen as the body or eye of Ra.

When later the god Amun rose to prominence, he was fused with Ra as Amun-Ra. During the Amarna Period, the pharaoh Akhenaten suppressed the cult of Ra proclaming another solar deity, the Aten, the deified solar disc, as the unique god. However, after the death (or murder) of Akhenaten the cult of Ra was restored.

It is interesting to remark that in astrology, it is assumed that the relative positions of celestial bodies and related details directly influence personality, human behavior, and social processes. It means that according to astrological principles, celestial bodies operate people and society.

In addition, the Sun operates the Earth and other planets of the Solar System by its gravitation force. Planets rotate around the Sun due to the gravitational forces. Besides, the light that comes from the Sun changes seasons in different parts of the Earth and some other planets.

Another important natural operator is the Earth. It also operates a variety of systems. The Earth gives water and other elements important for life to people, birds, animals and plants. All of them can exist only because they get water from earth. People, birds, animals and plants get oxygen, which is necessary for life, from the Earth's atmosphere. Conditions on the Earth surface regulate where it possible to grow useful plants and where it is impossible to do this. Even more, conditions of the Earth surface regulate where it possible to live, e.g., in Bern, Paris or Los Angeles, and where it is impossible to live, e.g., on the South pole or on the top of the mount Everest, which is called Chomolungma ("goddess mother of the world") in Tibet and Sagarmatha ("goddess of the sky") in Nepal. It means that the Earth operates all creatures living on it.

The great impact of the Earth on people and other living beings resulted in the fact that in many ancient societies the Earth was treated as a goddess. For instance, in Greek mythology, GAIA (or Gaea or Gea) was the primeval divinity of earth, one of the primal elements who first emerged at the dawn of creation, along with air, sea and sky. She was the great mother of all: the heavenly gods were descended from her union with Ouranos (the sky), the sea-gods from her union with Pontos (the sea), the Gigantes from her mating with Tartaros (the hell-pit) and mortal creatures were sprung or born from her earthy flesh.

The idea that the fertile earth as a goddess, nurturing mankind, also existed in other cultures. For instance, in Norse mythology, the feminine Fjörgyn (Old Norse "earth") is described as the mother of the god Thor. In Germanic paganism, the Earth Goddess is referred to as *Nertha*. In some cases, earth is personified by a god. For instance, the Egyptian earth and fertility god Geb was male and he was considered as father of all snakes.

In addition, the Earth operates the Moon and asteroids that come sufficiently close by its gravitation force. For instance, the Moon rotates around the Earth due to the gravitational forces of the Earth.

In turn, the Moon influences movement of waters in oceans and seas by its gravitation force. Thus, the Moon is also a natural operator with respect to waters in oceans and seas.

Wind is an example of a process natural operator, which operates (moves) the air, windmills, wind turbines, and wind pumps.

One more kind of important natural operators are chromosomes, which are the keepers of the genetic material in eukaryotic cells. They operate organisms of people, birds, animals and plants.

An organism has the same chromosomes for its entire life. A chromosome is an organized structure of DNA and protein that is found in cells. It is a single piece of coiled DNA containing many genes, regulatory elements and other nucleotide sequences. Each chromosome contains a single extremely long DNA molecule that is packaged by various proteins into a compact domain.Chromosomes also contain DNA-bound proteins, which serve to package the DNA and control its functions. The chromosomes are located within each cell nucleus. They provide the directions for how the cell is supposed to function. Thus, chromosomes are *natural cell operators*. Besides, chromosomes determine various characteristics about how the individual looks or functions. Thus, chromosomes are *natural organism operators*.

In a similar way, *genes*, which are the basic physical and functional units of heredity are *natural cell operators* and *natural organism operators*, as well as *natural protein operators* because genes are specific sequences of bases that encode instructions on how to make proteins.

In essence, any physical or biological object that interacts with and impacts other physical and/or biological objects is a natural operator.

It is important to understand that being an operator or an operand is a role and a characteristic of a system/object. One and the same system/object can be an operator in some situations and operand in other situations. For instance, when the inner structure of the Sun is studied, the Sun is treated as physical system with definite properties, which do not have operational character in this case. Although in many other situations, the Sun, as we have seen, is a natural operator.

Besides, a system/object can be an operator with respect to some systems and not an operator with respect to other systems. For instance, the Sun is an operator with respect to planets of the Solar System, while the Sun is not an operator with respect to distant stars that lie beyond the light cone of the Sun. The Earth is an operator with respect to the Moon and is an operand with respect to the Sun. Moreover, the Earth is an operator with respect to the Mars and at the same time, the Mars is an operator with respect to the Earth because the Earth influences the motion of the Mars and the Mars influences the motion of the Earth.

As we have seen the Earth operates people. At the same time, when by their activity, people change the atmosphere and climate on the Earth, the Earth becomes the operand and human society acquires the role of the Earth operator.

5. MACHINES AS OPERATORS

Usually machines are not treated as operators. They are operands (in our terminology) controlled by human operators. Here we extend our understanding of operators and this allows us to better characterize the role of machines in our society. Now, for example, a new tendency has arisen when machines are considered as operators but only when they are able to perform complex operations, and at least for a time work independently of people and operate, *e.g.*, control, some other machine. For instance, a robot can be an operator of another machine but traditionally it is not treated as an operator. A robot that explores the surface of the moon or planets must be able to walk on rough terrain in a harsh environment, receive instructions from remote operators about where to go next, and reach those commanded goals autonomously.

At the same time, it is customary to say that computers operate data. So, according to Definition **O1**, computers are operators. It may be less habitual but still acceptable to say that programs operate computers, but to hear that data operate computers seems rather strange. However, any manufacturing machine, e.g., loom or lathe, operates material from which the product of this machine is produced. Thus, this machine is an operator according to Definition **O1**.

This is especially true for robots, which become more and more abound. Industrial robots are found in a variety of locations including the automobile and manufacturing industries. Robots cut and shape fabricated parts, assemble machinery and inspect manufactured parts and perform many other manufacturing tasks. Outside the manufacturing world robots can be found in hazardous duty service, CAD/CAM design and prototyping, maintenance jobs, fighting fires, medical applications, military and agricultural operations and so on.

Some machines produce nothing, *e.g.*, a car or a plane. So, if we base our judgment on Definition **O1**, a car or plane is not an operator. However, a car, as well as a plane, bus, train or ship, operates things and people by taking them from one place to another. Nevertheless, there is an essential difference between humans and machines in their role of operators. What is considered unique in *humans* functioning as operators is the intentional relation between themselves and the object, tool or machine, which they operate or use as agents. In productive operation, there is thus an intentional relation between operators and the objects they create.

In the case of human beings, it is useful to differentiate between operation and intentional use, as well as between tool and machine. When spectators watch a movie in a theater, they use this movie but do not operate it. At the same time, operation can take place unintentionally. In such situations, it is possible to operate something but not to use it. For instance, when an individual destroys something, she does not use that thing.

There is also an essential difference between tools and machines. In philosophy, the concepts of machines and mechanisms refer to essences of things, while *being a tool* is a role of an object. For instance, a car is a machine whether it is used or not. It becomes a tool only when it is used for achieving some goal. There is also a discussion whether a human being is a machine in this sense or not when instrumentalized as a tool by and for another individual or a group, becoming an operand in the narrowest sense, that is, with the destruction of ethical reciprocity. As humans are created by nature as biological objects, it is more relevant to assume that they are not machines. This once more demonstrates the difference between tools and machines.

Tools in the form of physical machines are extensions of human physical and mental capacities. We nevertheless can only present a few key examples from the entire range of human activities, differentiated by *attitude and complexity.* One extreme is the (literally mindless!) repetitive operation of a machine epitomized by Charlie Chaplin in the film *Modern Times.* At the other extreme is the surgeon executing delicate operations that are now possible only through human-machine symbiosis.

René Thom, in his catastrophe theory, mathematically describes the process of using a tool or weapon. For instance, the form of an axe or projectile with a beveled edge, for example, is imagined by the maker as appropriate for causing a swallow-tail catastrophe (one of the seven basic types) in the skull of the animal or enemy. "The mental vision of the catastrophe to be provoked in the adversary creates a secondary field, that of the fabrication of the axe." (Thom 1972).

In LIR terms, the actual mental image process and the potential external effect as potential are dialectically connected. In this context, Lupasco (1947) discussed the operation of tools and machines, constructions of human beings and extensions of their capacities, in terms of a dialectic alternation between induction and deduction in science. He wrote that "after operating (sic) inductively, bringing to light theoretical phenomenological identities, it (physics) becomes deductive, in order to verify the effective actualization of these identities … ". Physics constructs machines and creates applied science such that this actualization implies that the objects fabricated should be rather considered fabricated *subjects*, since it is the agent, the operator-subject, the extension of the subject that is doing the actualizing of that theoretical identity. Deduction is the verification *operation* of inductive science.

What is unique in humans functioning as operators is the intentional relation between themselves and the object, *e.g.*, tool or machine, they operate and use. In productive operation, there is also the intentional relation between operators and products they create.

6. SELF-OPERATION AND SELF-OPERATORS

Self-operation is a phenomenon that refers to the ability of human operators and organizations of humans to operate on themselves, that is, recursively. The term self-operation actually includes a number of processes that also take place at lower levels of reality and thus, self-operation is abundant in nature, society and technology. Among the many kinds of self-operation studied by researchers and used for practical purposes are self-modification, self-organization, self-regulation, self-management, self-replication, self-production, self-control, and self-programming. All of these processes in the broadest sense refer to properties of a system to change both its internal environment (structure) and external behavior (functioning). In general, all of the natural and social operators that execute these operations are *ipso facto* self-operators. In this paper, we will limit our discussion to self-organization, self-control and self-regulation.

6.1. Self-Organization

We begin our discussion with the concept of self-organization in view of its importance for the understanding of all the reflexive processes, and because it illustrates the "operation" of the principles of Logic in Reality. The concept of self-organization was born in the 1960's in an attempt to establish a theory based on the standard logic of a system and its control.

The phenomenon of self-organization includes two sides (aspects): attributive, which is related to the inner structure of the system, and processual, which is related to the external behavior (functioning) of the system.

Definition 6.1 *Self-organization* in a broad sense is the property of a system to better organize its internal environment (structure) and external behavior (functioning).

We thus include the above two aspects in our definition of self-organization: attributive and processual. In attributive self-organization, some systemic property is improved. In processual self-organization, some system functioning (behavior) becomes more organized.

There are two main approaches to self-organization in social systems. One of them is based on the model of a system composed of aggregated individuals where self-organization is generated by and results in the sum of the practices in the system induced by control, or self-control, in particular, and system logic. The second approach focuses on the practices of individuals deviating from the logic of a system, making the existing system fluctuate and transforming its structure. That is why, to exist, any organization has to self-organize itself.

As a result, self-organization is related to emergence of pattern or regular structures. Thus, the following definition is very often used:

Definition 6.2 *Self-organization* is the process where a structure or pattern appears or grows in a system.

The problem in all discussions of self-organization as a kind of self-operation is to establish why some systems have the capacity to self-organize or to express self-organization and others do not. In fact, on close inspection, all systems to which self-organization is attributed depend for their capacity on some set of either initial conditions or on-going input of energy and information that transforms the term "self"- into a contradiction, correctly, a "self-contradiction". This brings us to two extreme types of self-organization: independent and induced.

Definition 6.3 *Independent self-organization* is a process where the organization (constraint, redundancy) of a system appears to spontaneously increase, *i.e.* without this increase being controlled by the environment or an encompassing or otherwise external system.

A 100% independent self-organization is in fact an ideal operation which is never realized in the process of system functioning.

In opposition to this pure type of self-organization stands induced self-organization or hetero-organization.

Definition 6.4 *Induced self-organization or hetero-organization* is a process where the organization (constraint, redundancy) of a system is seen to increase under the influence, e.g., pressure, persuasion or advice, from the environment or an encompassing or otherwise external system.

We have adopted here the term of Wu Kun (2010) to describe his approach to self-organization, namely, that it must always be accompanied, dialectically and functionally, by *non-self-organization* or, in his better term, hetero-organization. The problem to be resolved is then a proper definition of the interactions and differences between self- and hetero-organization.

For Wu, an ordered structure capable of self-organization is nevertheless dependent on the input of external energy and information for it to form and persist. It is not "spontaneously" generated within the system, even if it "spontaneously" forms. Once initiated, the process of self-organization does result in the creation of new entities. However, these require new (externally) available information for their further evolution. Hetero-organization refers, then, to a model for the delivery or introduction of this external information to the system.

The rigorous logical approach of LIR can be applied to the concept of self-organization. If one assumes a standard definition of a system, a self-organizing system is defined as distinguished by the formation of some states or entities arising from the reciprocal or collective interactions (encounters) between its components, *quite independently of outside inputs.* LIR theory, however, states that the critical terms of 'self' and 'independent' involve question-begging assumptions, given the critical LIR categorial feature of Non-Separability discussed above.

Brenner (2008) suggested that the critical step in the organization process is not spontaneous, in the sense of uncaused by outside agents, which the use of the particle "self-" without qualification implies. New organizational structures are the effective consequences of the potentialities residing in the components and/or introduced during the original constitution of the natural system or artificial experiment. This view supplements the discussion of self-organization in society proposed by Fuchs (2006), in which the emphasis is on a dialectical, emergent transition from simple elements defined by one or two parameters to more complex process-like entities instantiating quality or meaning. Fuchs also suggested the need for a new functional "logic of self-organization" in another recent paper. The advantage of LIR for a theory of organized systems is that it provides, at least, a partial answer to the question of why some systems self-organize, or display autopoiësis, and others do not. LIR simply takes the theory of self-organization and grounds it in (at least) one lower level of reality, without the need for invoking any non-causal spontaneous processes.

We propose, accordingly, that self-organization is not, in and of itself, a 'self'-evident mode of system formation and change. All self-organizing systems also involve some degree of organization-by-external-agent, which is a case of hetero-organization and the two are, again, dialectically related. Varela describes such a situation (Varela 1999) when he states that coupled non-linear oscillators can give rise to kinds of self-organization that result in the emergence of neural structures from the component level. A local-global interdependence is necessary to understand the emergence. The components "attain relevance" through their relation with their global counterpart.

We further characterize self-organization, within the limitations discussed above as gradual or apparently spontaneous. Gradual self-organization is a basically a process of evolution where the effect of the environment is minimal, *i.e.* where the development of new, complex structures takes place primarily in and through the system itself, subject to control by the initial conditions. In many cases, it can be understood on the basis of the same variation and natural selection processes as other environmentally-driven evolutionary processes.

In processes of apparent spontaneous self-organization, fluctuations often operate as organizing forces when at the global level of a system, patterms emerge mostly from numerous interactions among the lower-level components of the system, for example, through the "order through fluctuations" mechanism discovered by Ilya Prigogine (1980): systems which continuously export entropy in order to maintain their organization dissipative structures.

As a final type of apparent self-organization, we may discuss self-organization in the restricted systems sense (Haken 1993; Minati and Pessa 2006).

Definition 4.4.5 *Restricted self-organization* is the process where a structure or pattern appears in a system without a central authority or external element imposing it through planning and pressure, and is dependent on the prior potentialities of or initial conditions in or pertaining to the components of a system.

Therefore, many processes of restricted self-organization are in part therefore induced, involving hetero-organization.

Self-organizing processes in the restricted sense, such as herd behavior, groupthink and others, are abound in sociology, economics, behavioral finance and anthropology, as well as in economy, politics, industry, medicine, and technology. Biological science studies the creation of structures by social animals, such as many mammals and social insects (bees, ants, and termites), flocking behavior (such as the formation of flocks by birds, schools of fish, *etc*.).

In economy, we can see such self-organization processes as: growth, competition, extinction of companies; functioning of financial markets and stock markets. In politics, we have revolutions, "self-dynamics", formation of public opinion and development of beliefs. In social theory, the concept of self-organization was connected to self-referentiality and self-production by Luhmann (1995), who treated the elements of a social system as self-producing communications when a communication produces further communications and hence a social system can reproduce itself as long as there is dynamic communication. At the same time, human beings are sensors in the environment of the social system. Based on these foundations Luhmann developed an evolutionary theory of society, using functional analysis and systems theory.

Various social structures, such as organizations and institutions, have the form of a network. Self-organization in such networks is triggered and fueled by an ideology or sociological force that is adhered to or shared by all participants in the network. Self-organization in human (social) and computer (technological) networks can give rise to a decentralized, distributed, self-healing systems, helping the actors in the network to protect their security by limiting influence of the entire system on individual actors. Self-organization emerges in the network as a distinctive synergistic behavior through combination of the behaviors of individual actors in the network.

The phenomenon of self-organization in the restricted sense also exists in many domains of nature, such as chemistry or biology. Examples of self-organization in the restricted sense in chemistry are molecular self-assembly, reaction-diffusion systems and oscillating chemical reactions, autocatalytic networks, liquid crystals, colloidal crystals, self-assembled monolayers, and microphase separation of block copolymers. Examples of self-organization in the restricted sense in biology are spontaneous folding of proteins and other biomacromolecules, formation of lipid bilayer membranes, pattern formation and morphogenesis, the coordination of human movement, the creation of structures by social animals discussed above.

The standard theoretical treatment of self-organization in the restricted sense is based both on microscopic, as well as macroscopic phenomenological approaches. Haken (1993) formulated general principles of self-organization in the restricted sense or self-organization as the reduction of complexity. They are based on general concepts, such as order parameters and the slaving principle. For instance, in large classes of systems their dynamics can be described by few order parameters.

In our view, however, the phenomenon of self-organization in the restricted sense for which many more examples could be given in chemistry, biology and sociology are all dependent on the preexisting residual potentials present in the components of the system in its initial state. Since systems, accordingly, do not self-organize “by themselves”, the possibilities for changing the evolution of the systems are limited.

The consequences, particularly in the social field are significant. For example, there are two main approaches to self-organization in social systems. One of them is based on the model of a system composed of aggregated individuals where self-organization is generated by and results in the sum of the practices in the system induced by control, or self-control, in particular, and the logic of the system logic. The second approach focuses on the practices of individuals as agents deviating from the logic of a system, making the existing system fluctuate and transforming its structure. The original capacities of such individuals to make changes should not, accordingly, be considered as part of the self-organization that is alleged to occur.

6.2. Self-Control

Proceeding from the above general principles to self-operation in human beings, we look at the process of self-control.

Definition 4.4.6 *Self-control* in a broad sense is the property of a system to control itself, *i.e.*, its internal processes and external behavior (functioning).

The concepts of self-regulation (see next sub-Section) and self-control are very close to one another. However, the concept of self-regulation is more popular in system theory and cybernetics, while the concept of self-control is more popular in psychology. For instance, emotional self-control: presupposes keeping disruptive emotions and impulses under control. An example of self-control is when one manipulates one's own behavior by affecting states of deprivation or satiation. Psychological self-control means the ability to control one's emotions, behavior and desires in order to reach some goal, as well as the capacity of efficient behavior oriented at the future.

In society, self-control of an individual is directly related to the pressure/influence the individual may face. Thus, it is possible to distinguish three situations: good pressure/influence, bad pressure/influence and no pressure/influence. An example of a good pressure/influence is when an individual is in a competitive, yet non-judgmental and non-prejudicial environment and wants to be like those around. This makes the individual motivated and inspired to gain self-control. On the other hand, when an individual is in a judgmental and prejudicial environment, the individual may become depressed and unmotivated, losing self-control. In the third case, when an individual is free and there is no competition, self-control is based on how an individual may feel.

Skinner (1953) gives a survey of nine categories of self-control methods. They include physical restraint and physical aid, changing the stimulus, drugs, operant conditioning, punishment depriving and satiating, manipulating emotional conditions, using aversive stimulation, and doing something else.

Manz *et al*. (2002) argue that self-control is at the core of the organizational control process, expanding, in such a way, the view of control is developed in which importance of self-control, as well as external control mechanisms are recognized. For example, many companies are trying to become learning organizations often using self-control rather than relying on rules and regulations. Thus we can see that the difference between self-regulation and self-control is that self-control demands intentionality, while self-regulation, as a rule, does not need it.

6.3. Self-Regulation

The next most general category within the framework of self-operation is self-regulation.

Definition 4.4.7 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*. Self-regulating systems exist on all levels: cells in an organism, human organism, and many social organizations are self-regulating systems.

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 and sends information about these changes to the control unit; 2) the *control unit* (or *conceptor* in the sense of (Burgin and Gladun 1989)) 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).

Information plays a crucial role in self-regulation, which is often based on the feedback of the system. It is possible to understand self-regulation through the interplay of positive and negative feedback cycles when 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) and negative feedback because it stabilizes these parameters.

- Human Domain

Let us take the human organism as an example of a self-regulating system. In it, most homeostatic regulation is controlled by the release of hormones into the bloodstream, while other regulatory processes rely on simple diffusion to maintain a balance. The process of self-regulation proceeds as follows. The receptor system, which may consists of several components or even of many autonomous units, is sensing different stimuli. When a relevant stimulus comes, the receptor sends information to the control unit, finds the state/phase of the organism and determines an appropriate response to the stimulus. In the human organism, the control unit (control center) is the brain. Then the control center sends signals to the effector system or to a part of this system, which can be muscles, organs or other structures that receive signals from the control center. After receiving the signal, a change occurs to correct the deviation by either enhancing it with positive feedback or depressing it with negative feedback

Neural networks, both natural and artificial usually work in the same way, having the alike components: receptors, conceptors and effectors (Burgin, Gladun 1989). Very often state self-regulation is aimed at homeostasis, derived from the Greek hómoios, "similar" and stásis, "standing still". The term was defined by Claude Bernard in the 19th Century and by Walter Bradford Cannon in the 20th Century.

- Social Domain

There are two main approaches to self-organization in social systems. One of them is based on the model of a system composed of aggregated individuals where self-organization is generated by and results in the sum of the practices in the system induced by control, or self-control, in particular, and system logic. The second approach focuses on the practices of individuals deviating from the logic of a system, making the existing system fluctuate and transforming its structure.

The whole existence of social organizations, such as companies, corporations, states, social institutions, or societies, is, as a rule, based on self-regulation (Baumeister, Vohs 2004). Self-regulation is closely connected to autonomy and independence. The more autonomous/independent system is the more self-regulation it needs and it has. For instance, a completely independent state is self-regulated, while a colony is regulated by the country that owns it. A self-regulating social organization elaborates regulatory standards, such as Code of Ethics, Code of Conduct, Constitution, etc., and then enforces these standards. In social organizations, self regulation mechanisms are usually composed in the Triad of Power (Burgin 1997). The first component of the Triad, the Legislative Power, elaborates regulatory standards of the organization. The second component of the Triad, the Executive Power, enforces and preserves the regulatory standards of the organization. For instance, all organizations in business and industry have a management structure, which determines relationships between functions and positions, and subdivides and delegates roles, responsibilities, and authority to carry out defined tasks. The third component of the Triad, the Judicial Power, functions as a mediator between the Legislative Power and the Executive Power. Note that in organizations two or even all three powers can coincide and be embodied in one and the same group or even one person as it exists, for example, in dictatorships.

There are different foundations for self-regulation. In some organizations, self-regulation mechanisms are built on trust when people work together, taking the process forward, while in totalitarian organizations, self-regulation mechanisms are built on fear on the state level, as in Nazi Germany and the Soviet Union, or in criminal societies, with no internalized values or regulatory standards other than that of the group.

Different aspects of self-regulation in society can also be identified. For instance, a domino-effect can occur when small changes by a few organizations can impact society as a whole. Revolutions in different countries, e.g. in France, Russia or Iran, are examples of such changes. At the same time, self-regulating organizations can emphasize and reinforce their accountability to different participants in the process of functioning, with the potential for improving accountability towards the community and beneficiaries as well.

7. CONCLUSIONS

Our intention is to develop the concept of operators in both theoretical and practical directions. Our approach, which uses the tools of 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 are derivable from *natural operators*. It would be interesting to study *symbolic operators* in information technology and computer science. Such operators are extremely important in the evolving information society.

Operators allow one to explore relations between nature and society in a formalized way, following approaches in physics and biology. It is possible to suggest that the natural-social operator split provides a key criterion for determining what entities may be considered autonomous, morally responsible agents.

References

Baumeister, R.R. and Vohs, K.D. (Eds.) (2004) Handbook of Self-Regulation: Research, Theory, and Applications. Guilford Press, NewYork

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

Bennett, M.R. and Hacker, P.M.S. (2003) Philosophical Foundations of Neuroscience. Blackwell Publishing, Massachusetts

Bickhard, M.H. (2009) The interactivist model, Synthese, v. 166:547-591

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

Brenner, J.E. (2008) Logic in Reality. Springer, Dordrecht

Brenner, J.E. (2010a) The Philosophical Logic of Stéphane Lupasco. Logic and Logical Philosophy 19 (3):243-285

Brenner, J.E. (2010b) Stéphane Lupasco et la Rejonction Métalogique. In: A la confluence de deux cultures. Lupasco aujourd'hui. Proceedings of the International UNESCO Colloquium, Paris, March 24, 2010. Editions Oxus, Paris, pp 250-285

Brown, P. and Lauder, H. (2001) Human Capital, Social Capital and Collective Intelligence. In: Social Capital: Critical Perspectives, Oxford University Press, Oxford, pp 226-242

Burgin, M. (1993a) Triad as a Fundamental Structure in Human Culture. Studia Culturologia 2:51-63

Burgin, M. (1993b) On the way to the "Absolute": Triad is the most fundamental structure in human society. Journal of the Academy of Science of Ukraine, v. 5:29-35

Burgin, M. (1997) The Triad of Power. In: Politological Encyclopedic Dictionary. Geneza, Kyiv, pp 353-354

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

Burgin, M. and Gladun, V. (1989) Mathematical Foundations of the Semantic Networks Theory. Lecture Notes in Computer Science 364:117-135

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

Castells, M. (2000) The Information Age: Economy, Society and Culture. Vol. I The Rise of the Network Society, Blackwell Publishing, Malden-Oxford-Carlton

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

Csanyi, V. (1989) Evolutionary Systems and Society. Duke University Press, Durham/London

Daft, R.L. (1998) Organization: Theory and Design. South-western College Publishing, Florence, KY

Davies, E.B. and Lewis, J.T. (1970) An Operational Approach to Quantum Probability. Commun. Math. Phys. 17: 239-260

D'Entreves, M.P. (2008) Hannah Arendt. In: Zalta, E.N. (Ed.) The Stanford Encyclopedia of Philosophy (Fall 2008 Edition). URL=http://plato.stanford.edu/archives/fall2008/entries/arendt/

Dowe, P. (2008) Causal Processes. In: Zalta, E.N. (Ed.) The Stanford Encyclopedia of Philosophy (Fall 2008 Edition). URL= http://plato.standford.edu/archives/fall2008/entries/causation-process/

Esfeld, M. and Lam, V. (2010) Holism and Structural Realism. In: Vanderbeeken R, Weber E (Eds) Worldviews Science and Us; Studies of analytical metaphysics

Ghils, P. (1994) Les tensions du langage. Peter Lang, Berne/Berlin

Giddens, A. (1984) The Constitution of Society. Polity Press, Cambridge, U.K.

Gregg, D.G. (2010) Designing for collective intelligence. Communications of the ACM 53(4):134-138

Haken, H, (1993) Advanced Synergetics: Instability Hierarchies of Self-Organizing Systems and Devices. Springer-Verlag, New York

Heisenberg, W. (1925) Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen. Zeitschrift für Physik 33:879-893

Jacquette, D. (2007) Philosophy of Logic. In: Gabbay D, Woods J, Thagard P (Eds.) Handbook of the Philosophy of Science Series. North-Holland Press (Elsevier), Amsterdam

Jung, C.G. (1969) The Structure and Dynamics of the Psyche. Princeton University Press, Princeton

Jung, C.G. (1971) Two Essays on Analytical Psychology (trans. R.F. Hull). World Publishing (Meridian), New York and Cleveland, pp. 63-71

Kaye, D. (1995) The nature of information. Library Review 44(8):37–48

Kiel, L.D. (Ed.) (2001) Knowledge Management, Organizational Intelligence and Learning, and Complexity. EOLSS Publishers, Oxford

Kraus, K. (1983) States, Effects, and Operations. Springer Verlag, Berlin

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

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

Leydesdorff, L. (2009) Redundancy in Systems which Entertain a Model of Themselves: Interaction Information and the Self-organization of Anticipation. Preprint for *ENTROPY*

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

Ludwig, G. (1964) Versuch einer axiomatischen Grundlegung der Quantenmechanik und allgemeinerer physikalischer Theorien. Zeitschrift für Physik 181:233-260

Luhmann, N. (1995) Social Systems. Stanford University Press, Stanford

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

Lupasco, S. (1947) Logique et contradiction. Presses Universitaires de France, Paris

Lupasco, S. (1951) Le principe d'antagonisme et la logique de l'énergie, Éditions Hermann, Paris

Lupasco, S. (1962) *L'énergie et la matière vivante.* Julliard, Paris

Magnani, L. (2002) Preface to Model Based Reasoning. In: Magnani, L. and Nersessian, N.J. (Eds.) Science, Technology, Values. Kluwer, Dordrecht

Magnani, L. (2007) Morality in a Technological World. Knowledge as Duty, Cambridge University Press, New York

Manz, C.C. and Mossholder KW, Luthanvs F (2002) Controlling Information Systems Development Projects: The View from the Client. Management Science 48:484-498

Minati, G. and Pessa, E. (2006) Collective Beings. Dordrecht, Springer

Nguen, N.T. (2008) Inconsistency of knowledge and collective intelligence. Cybernetics and Systems 39(6): 542-562

Nicolescu, B. (2002) Manifesto of Transdisciplinarity. State University of New York Press, Albany, N.Y.

Nonaka, I. and Takeuchi, H. (1995) The Knowledge Creating Company. Oxford University Press, Oxford

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

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

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

Seibt, J. (2009) Forms of emergent interaction in General Process Theory. SYNTHESE 166:479-512

Sinden, R. (1994) DNA structure and function. Elsevier, Amsterdam

Skinner, B.F. (1953) Science and Human Behavior. Simon&Schuster, New York

Smiley, M. (2008) Collective Responsibility. In: Zalta E.N. (Ed.) The Stanford Encyclopedia of Philosophy (Fall 2008 Edition) URL=http://plato.stanford.edu/archives/fall2008/entries/collective-responsibility/

Smith, D.W. (1999) Intentionality Naturalized? In: Petitot, J., et al (Eds.) Naturalizing Phenomenology. Issues in Contemporary Phenomenology and Cognitive Science, Stanford University Press, Stanford

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

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

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

Suroweicki, J. (2004) The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations. Little Brown, Boston

Szuba, T. (2001) Computational Collective Intelligence. Wiley, New York

Thom, R. (1972) Stabilité structurelle et morphogénèse. W. A. Benjamin, Inc., Reading, Mass.

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

Varela, F.J. (1999) The Specious Present. In: Petitot J et al (Eds.) Naturalizing Phenomenology. Issues in Contemporary Phenomenology and Cognitive Science.. Stanford University Press, Stanford.

Weiss, A. (2005) The Power of Collective Intelligence, netWorker - Beyond file-sharing. Collective Intelligence 9(3): 16-24

Wheeler, J.A. (1990) Information, Physics, Quantum: The Search for Links. In: Zurek W. (Ed.) Complexity, Entropy, and the Physics of Information, Addison-Wesley, Redwood City, CA, pp 3–28

Woodward, J. (2001) Causation and Manipulability. In: Zalta EN (ed) Stanford Encyclopedia of Philosophy (Fall 2001 Edition). URL= http://plato.stanford.edu/archives/fall2001/entries/causation-mani/.

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