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KNOWLEDGE RECOMBINATION ON THE INFORMATIONAL ADAPTABILITY OF CELLS, NERVOUS SYSTEMS, AND SOCIETIES

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Abstract: *New abstractions and new procedures for abstraction are needed in information science. Some of them should concern the nature and function of knowledge regarding the adaptability of complex, informational entities. Knowledge "in action" manifests itself as an improved adaptability of the informational entity to its environment, and as a redirection and enlargement of its self-construction processes. If taken beyond its usual anthropocentric conception, knowledge not only underlies the guidance of human actions and perceptions within appropriately restricted cognitive settings (or disciplinary fields), it also orientates –among others– the biomolecular happenstances of cells, and the processual workings of individual nervous systems. And it does so, as will be argued here, by incurring in a peculiar dynamics of similar recombination processes performed upon heterogeneous repositories of very different physical nature, which factually increase the cognizing reach of the concerned informational entity and leverage the conquest of further adaptability niches and complexity developments. Actually the growth of informational complexity of cells, nervous systems, and societies along their respective evolutionary, ontogenetic, and historical trajectories has been based on the cumulative consequences of knowledge recombination phenomena. However, the recognition of this commonality has been obscured, among other causes, by the structural and dynamic heterogeneity of repositories in the different informational entities, and by being subject of quite separated scientific disciplines: molecular and evolutionary biology, cognitive neurodynamics, philosophy of science/"geography" of science. In the extent to which such commonalities may be elucidated from a new vantage point, it would help in the development of information science itself, as well as in the pragmatics of education, in the social organization of science, and in the research effort of contemporary societies. Finally, the new term of "scientomics" is proposed in order to capture the knowledge combinatory processes and disciplinary mixings within the sciences.*

Keywords: *Information science, Knowledge recombination, Cells, Nervous systems, Neurodynamic central theory, Scientific recombination, Scientomics*

1. Introduction

The literature about information is growing at an accelerated pace. A good portion of it, however, is still devoted to a very traditional and controversial game: the definition of information. The concept was left factually undefined in its most controversial aspects (at least in its connection with meaning, knowledge, and intelligence) by the founding fathers of the field in the 40's and 50's; and not much progress has been achieved afterwards, in spite of the successive workings of almost two generations of scholars. On the one side, the boom of new computer science fields like artificial intelligence, artificial life, and biocomputing during the 70's and 80's, together with the expansion of complexity sciences during the 90's, did not leave many relevant scholars interested in further explorations of the information paradigm (with the exception of technical applications in communication engineering, encoding and computing, DNA & molecular machines, etc.). On the other side, the dominant position of information technologies and the collective hype and "tunnel vision" promoted by techno-utopians, i-companies, e-learning, information society theoreticians, etc., were not very helpful for enlightening the debate either. Why should theoreticians of the proclaimed “information society” take care about misunderstandings and paradoxes of the i-term within the sciences? (Castells, 2000).

Is information *definable*? Rather then continuing with narrow discussions focused on a single concept (for which hundreds of definitions have been proposed along these decades!) some parties were proposing an alternative course, to be focused on rigorous disciplinary development (Conrad, 1996; Marijuán, 1996; Scarrott, 1998): *“From its very beginnings in early 90’s, the FIS initiative (Foundations of Information Science) has been an attempt to rescue the information concept out from its classical controversies and use it as a central scientific tool, so as to serve as a basis for a new, fundamental disciplinary development –Information Science... At FIS, rather than the discussion of a single particularized concept, information becomes the intellectual adventure of developing a ‘vertical’ or ‘transdisciplinary’ science connecting the different threads and scales of informational processes, which demands both a unifying and a multi-perspective approach. Above all, the solution of the numerous conundrums and conceptual puzzles around information becomes the patient task of a community of scholars, in which the ideas and speculations of each individual thinker can be shared and experienced upon by the other colleagues, so that a sort of ‘group mind’ develops (paraphrasing L. Hyde, 1979): one that is capable of cognitive tasks beyond the power of any single person.”* (see Marijuán, 1996, at: http://infoscience-fis.unizar.es/c_1.html)

The position of this paper is that the advancement of information science has to produce new kinds of abstractions. Some of them will refer to information itself (and to its relationship with meaning), others to intelligence, and as a sort of bridge between the two, there should be new abstractions on the obtention and validation of knowledge (Marijuán, 2010; Yixin, 2010). This trio of “impossible” concepts —information, knowledge, intelligence— conform the pillars upon which a future information science has to be properly founded.

Herein, rather than attempting a definition of the knowledge concept, or setting its reach in an arbitrary way, we will consider it throughout its performances *in action.* We will point to three different realms, apparently quite heterogeneous and incongruous ones, where knowledge repositories and processes of very different nature can be detected as forming part of a nucleus of informational combinatory processes that grant the adaptability of the concerned entity to its environment. Notwithstanding the enormous dissimilarity of cells, nervous systems and human societies, in all of them heterogeneous recombination processes are performed at very different time scales upon a variety of knowledge-repository supports, either molecular encodings, memory constellations, or scientific-disciplinary contents, which somehow recapitulate each other along convoluted dynamic and evolutionary hierarchies.

A homogeneous description is out of hand—these informational entities belong to conceptual disciplines worlds apart. Thus the strategy of this paper will consist in attempting an independent description of information-knowledge processes for each one of the entities, to be followed then by some tentative abstractions/conclusions interrelating them “vertically”, so to speak (Conrad, 1996). As will be argued, the main emphasis in this too brief a paper should be put on the close relationships between the evolutionary handling of molecular knowledge or *domain recombination* —combinations of protein domains throughout successive generations of living cells— versus the most sophisticate kind of cognitive games socially performed on scientific knowledge: the *interdisciplinary* recombination process performed within the system of sciences (Marijuán, 1996; Scott, 1998). In this sense, the development of a genuine *scientomics* borrowing concepts and techniques from bioinformatics will be proposed.

2. The Cell as an informational paradigm

The comparative advantage of the cellular information paradigm is that it can be properly described molecularly, almost to completion. At least in prokaryotic cells, almost all the molecular components are relatively well known, either as metabolites, or as protein-enzyme components, molecular machines, genomic sequences, etc. Evolutionarily, the living cell has been the first *informational* entity: endowed with self-production processes, communication with the environment, and an inner population of protein-agents coded into a genome. However, the extraordinary multiplicity of informational processes within the cell goes far beyond any traditional conceptualization of biological information either as code, communication, or structure. It is a dynamic world teeming up with millions of specific molecular recognition events, multiple codes, transcriptions, translations, processors, signalling systems, messengers, effectors, second messengers, regulators, interferences, complexes, connectivity networks… A very brief synthesis of its basic information processes will be discussed in what follows.

2.1. Cellular self-production

Essentially the cellular game is about a collective problem-solving dynamics applied to self-production of the own structures —implying both synthesis and degradation— which is performed by a "network society" of specialized enzyme and protein agents, continuously exchanging information about their specific activities thanks to the especial solvent properties of the water matrix. In response to *communicational* signals of the environment, thousands of *constitutive* enzymes and proteins, "nanomolecular processors" endowed with a peculiar modular structure, are synthesized (and also degraded) out from the sequential *generative* information of the DNA and RNA "data bases", which are themselves incessantly subject to evolutionary combinatory games (Marijuán, 2002).

There appear multiple varieties of biomolecular information to distinguish (at least, the three broad categories mentioned: *constitutive*, *generative*, and *communicational*). In the interplay of all those varieties of information, the tides of self-production processes are orchestrated in a complex and flexible way, harmoniously engaging synthesis and degradation on an equal footing —the functional importance of both "negative phenomena", protein & RNA degradation and apoptosis, or cell death, cannot be overestimated. The whole productive-informational processes culminate in the regularity of a specific cell-cycle that is *open* to the environment, both in terms of energy and information.

The elements of the constitutive architecture ("diluted" enzymes and proteins) are all of them coded into the generative architecture ("sequential" DNA & RNA), and the functional control of the latter by the former provides the core self-production and self-modification capabilities of the system —how gene expression is controlled by transcription factors. Traditionally most studies have focused in the expression of individual genes and not in the overall network and systemic instances of control. Currently, however, massive transcriptional regulatory networks are built for different prokaryotic microorganisms and eukaryotic cellular functions and specialized cell-types.

As an instance of such networks, the author's research team has cooperated in compiling a large-scale *M. tuberculosis* transcriptional regulatory network, which has been built upon a previously published TR network (Balázsi et al., 2008) the largest to date, with further addition of different kinds of resources pertaining to publicly available sources: DNA microarrays, operons, orthology approaches, and synthetic biology experiments (Navarro et al., 2010). See Figure 1.

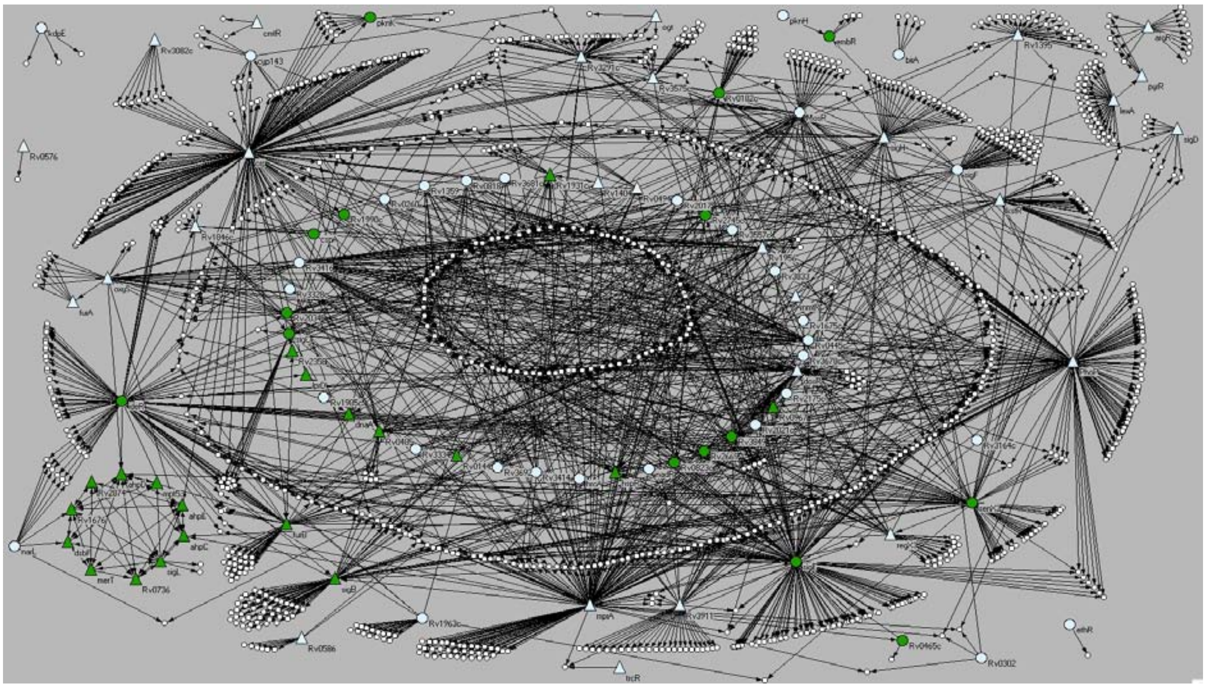

Figure 1. The Transcriptional-Regulatory (ETR) Network of *M. tuberculosis*.

In Figure 1, nodes represent *Mt*'s genes, and links represent their regulatory interactions. Transcription factors appear either green or blue, depending on whether they have known transcriptional regulator or not. The white nodes represent output elements without transcriptional activity. The triangle nodes represent protein transcription factors that auto-regulate their own expression. Approximately 35% of the genome is covered by this network. (Modified from: Navarro, 2010).

The 1,400 network nodes represented correspond all of them to specific genes of *M. tuberculosis* and their protein products, while the 2,304 links correspond to gene expression regulatory interactions by 94 transcription factors. The network shows a clear organization in structural levels that correspond with the complex functions and life-cycle stages of this highly sophisticate pathogen. Overall, the genome of the bacillus contains more than 4,000 genes and close to 190 transcription factors. In general, an increased number of transcription factors per genome translate into greater genetic network connectivity, which is correlated with increased complexity of the microorganism structures and life cycle (Levine & Tjian, 2003).

2.2. Cellular signaling

By itself the transcription network is "blind". In other words, the coupling between the sequential and the diluted architectures needs the injection of further adaptive capability to respond to environmental demands. This is done by means of signaling guidance, so to partially deploy the genetic circuits in response to relevant happenstances of the environment or from within the cell. The *topological governance* of the transcription regulatory network, the decision of what parts should be activated or what particular circuits should be inhibited, is achieved thus by the cellular signaling system or *signalome.*

In prokaryotes, a variety of molecular systems are involved in the signalome, ranging from simple transcription-sensory regulators (a single protein comprising two domains), such as the well-known *embR, alkA* or *furB*, to those systems of multiple components and interconnected pathways that regulate key stages of the cell cycle, such as latency, pathogenesis, replication, and dispersion. A basic taxonomy of bacterial signaling systems was proposed somewhere else (Marijuán et al., 2010), which was centered on “the 1-2-3 scheme.”

In eukaryotes, the signaling system comprises many hundreds of different classes of dedicated molecular agents (receptors, ion channels, transducers, amplification cascades, second messengers, intermediate effectors, final effectors) that can be arranged differently in each tissue. Particularly throughout the very fast changes in second messenger concentrations, an integrated perspective (measurement) of the different internal and external influences at play is obtained within the cell, and is subsequently passed towards intermediate chains and the final effectors.

At the end of the signaling command-chain, the gene expression machinery is waiting to be fed with a combination of *ad hoc* signals in order to change the transcriptional status of the genome –so that the well measured signals from the cytoplasmic signalome may be finally enacted as a new transcription program in relation with the advancement of the cell cycle or with the specialized function of the cell (Janes et al., 2005).

2.3. Cellular knowledge in action

The living cell enacts a new way of existence, an active “informational” one that is based on the capability to keep the own structures in a permanent state of “flow”, piling up synthesis and degradation processes in a way that reminds critically self-organized phenomena (Marijuán, 2004). Thus, the living cell may systematically respond to signals from the environment, and produce the “meaning” they imply, by letting the signals themselves to interfere with the ongoing molecular dynamics of the cellular self-production “flow”. Therefore, *meaning* may be defined throughout molecular *mining*: as the (signal) induced changes in components and connectivity of the constitutive enzyme-protein populations and the associate metabolites and substrates. The *relevance* and *value* of the signal can subsequently be considered and gauged —cellularly, this would correspond to second messengers and the cycle “checkpoints”. Completion of the cell cycle always appears as the fundamental reference. The phenomenon of *knowledge* may be appended too, once the generative codes of the elements implementing successful responses have been evolutionarily selected, refined, and cohered within the life cycle (Marijuán & del Moral, 2007).

“Evolvability”, understood as computational efficiency in the elaboration of DNA adaptive knowledge, has been largely increased along the evolutionary process itself. Because of the DNA modular organization of its domain based “addresses”, the evolutionary genetic algorithms for physiological problem solving become largely parallelized. The different components of the biomolecular solutions may be separately tinkered with in different domains, and linked together later on (Peisajovich et al. 2010). Besides, every molecular stage (transcription, folding, transportation, modification, complexes, degradation), specifically coded onto DNA addresses, may be used as a new functional element of control. Solutions may be chosen, then, from an augmented set of molecular building blocks. The so called “Central Dogma” of classical molecular biology should not be taken as a closed, linear production-chart; rather the successive stages and intermediate transcripts could participate as legitimate molecular partners, each one endowed with endogenous recognition capabilities, within a whole *transmolecular matrix* of controlling interactions (Marijuán, 2002, 2004). We might argue that prokaryotes have used those very capabilities mostly towards the direct solution of *molecular assimilation* problems (in their encounter with environmental substances), while eukaryotes have tamed a fascinating developmental complexity by evolving towards the general solution of *molecular organization* problems.

Most of that complexity growth has been built by tinkering upon multi-domain enzymes and proteins, so that primary function codes or addresses and secondary addresses regarding the circumstances of the primary functions have been put together (though often in separate domains) onto the same DNA memory bank. Then the parallel with the von Neumann scheme of modern computers seems unavoidable: for memory addresses and logical functions are also put together into the CPU memory of computers. Further interpretations of cellular organization in "computer terms" have recently been made: Danchin (2009) about analogies with Turing machines, and Yan (2010) on operating systems.

From the knowledge perspective of this article it is important realizing that, by means of bioinformatic tools, one can track down how the different combinations of protein domain families have been progressively formed within genes, generating new protein domains and new gene families in a sort of "bing bang" of protein evolution, from the early forms of life to the more modern genera. Very old domains can be visualized as they have interpenetrated and recombined with recent domains within more complex proteins, following prokaryote horizontal gene transfer as well as genetic recombinations of all kind in both prokaryotes and eukaryotes, systemically *putting into action* more efficient genomes with improved sets of protein domain functionalities (primary functions plus the retinue of accompanying functional circumstances). The existing protein domains coded into the genomic DNA and their combinatory processes may be seen as the stock of knowledge of each species and, globally, of the biosphere as a whole. Genomes are continuously in the making, self-adapting and trying new knowledge solutions for each individual species as an existential answer to the selective demands posed by every particular niche.

3. Brains and knowledge: Towards a Neurodynamic Central Theory

The transition from cells to brains implies an important change concerning the disciplinary backgrounds –and even more concerning the problems to be tackled. In information terms, the study of information-knowledge in advanced brains bears a significant disadvantage, notwithstanding the anthropocentric familiarity it inevitably conveys. Arguably, one of the most dramatic absences in contemporary science concerns the lack of a central theory in the neurosciences. The revolutionary changes occurred in most neuroscientific disciplines (computational, cognitive, physiological, behavioral, network analysis, neuropsychiatry...) during recent decades have not been accompanied by the development of integrative theories yet, capable of introducing a new sense and a new order upon the data deluge received. The absence of a *central neurodynamic theory*, similar to the Darwinian Theory central role in the biological realm (or classical mechanics in physics), is creating an intellectual vacuum that negatively influences in the neurosciences themselves, as well as in their relationships with other technological and social disciplines. The basis of a possible theoretical development in that direction, related with knowledge production too, will be drafted in what follows.

3.1. Development of an integrative attempt

The NCT scheme ("Neurodynamic Central Theory") addresses a new way of explaining the organization of brain information processes (Marijuán & Panetsos, 2011). It establishes the correspondence between neurodynamics and behavior by means of a central theory grounded on dynamic connectivity (conectome) and on optimality (principles of brain economy). As the core of this theory, it is proposed the development of an informational "behavioral-processual engine" ingraining the multidimensional operations of composition-decomposition of sensorimotor afferences and efferences with the realization of an action/perception cycle, producing adaptive behavior and associative learning (efficient knowledge) as outcomes. A number of disparate behavioral and cognitive aspects might be unified out from the development of this theory, including the recently coined brain's "dark energy" (Raichle, 2006, 2010) and the global "workspace" proposed by Changeux, Dehaene, and others (Dehaene et al., 2001).

To reiterate, a new integrative theory is badly needed, a radically whole new approach rather than the piece-meal approach followed in most theoretizations of neuroscientific disciplines. The ongoing neurocomputational, neuromolecular, neuroinformatic and neuroimaging revolutions (to name but a few of the emerging disciplines responsible of the enormous experimental data-accumulation taking place in neurosciences) have not been accompanied by any parsimonious synthetic approach yet. Very recent findings about the "Conectome" need to be elaborated and generalized, both in their theoretical interpretation and in their experimental content (Zamora-López, 2010; Sporns, 2011). The dynamic "Conectome" has to be interpreted in terms of supersystem configurations of an information processing engine realized by cortical areas and medial nuclei, along an optimization process of local/global nature, and following symmetry-breaking/symmetry-restoration operations that make each cortically stored information unique and recoverable (Collins, 1991; Collins & Marijuan, 1997; Turvey, 2004). In the optimality aspect, the NCT scheme integrates those findings with principles of maximum economy in space and time, and with symmetry-breaking and group theory concepts for distributed processes that will configure a hierarchical-heterarchical scheme of information processing, learning and adaptive behavior (Marijuán, 2001).

The NCT paradigm gives sense to a number of recent studies on cortical connectivity, which are disclosing a highly complex panorama of neural activations in multiple areas and regions that are integrated into transient constructs of almost unknown behavioral functionality (where the phenomenon of consciousness might be appended). Some of these works about the "Conectome" have pointed at the emergence of dynamic core aggregates that fleetingly appear and disappear in milliseconds after any complex stimulus or mental process (originated either from the "outside" or from the "inside"). Such unending dynamics of fleeting aggregates has recently been dubbed as the brain's *"dark energy"*, and different cognitive-behavioral interpretations have been suggested, but until now they have not conduced to any sensible scheme (Raichle, 2006, 2010).

The NCT opens up a new research direction in the genuine organizational principles of *autonomy* that have guided the evolution of information processing in the vertebrate CNS. The "virtual reality" generated by the CNS out from the open-ended internal and external data affordances represents but the fitness occasions that the animal confronts as an autonomous agent in its environment. Autonomous agent theory, as well as the development of non-von-Neumann architectures (parallel processing), are closely related to this new type of information processing "engines".

3.2. A new approach to human knowledge

In the human case (and in most advanced central nervous systems), it is the *action/perception* cycle what serves as the universal substratum for organizing behavior and subsequently tending the fabrication of meaning, categories and knowledge. Seemingly, we confront the world in accordance with such action/perception cycles or oscillations, regularly switching between dominant modes of behavior (motor centered versus sensory centered). The advancement of the cycle is based on a global minimization process performed upon an entropic global/local variable that cortical columns and medial nuclei cooperatively create and annihilate upon a local basis, but also mediated by the organization of variable supersystem configurations, and implying formal rules of symmetry-breaking and symmetry-restoration. It is the informational *"behavioral-processual engine"* that ingrains the multidimensional operations of composition-decomposition of sensorimotor afferences with the realization of an action/perception cycle, producing (thalamicaly mediated) adaptive behavior and associative learning outcomes.

The brain appears as an abstract problem-solving playground where topologically distributed variables (“tuning precision voids”) occurring at the neuronal columns of cerebral maps are processed as some overall entropy that different brain substructures and specialized modules tend to minimize. Because of the evolutionary design of nervous systems (e.g., the vertebrate phenomenon of *decussation* of the nerve fibers) internal and external organismic “problems” locally increase that entropy value. The subsequent blind (abstract) minimization by the nervous system’s topological mechanisms and modular specialized subsystems produces as a byproduct the adequate behavioral and learning outputs. A problem-solving behavior well adapted to the advancement of the individual’s life cycle emerges from all those distributed processes and minimization operations (Marijuán, 1996b).

It is of particular interest in the human case that the combined system formed by the frontal and prefrontal areas with their massive increase in connectivity are breaking the brain’s reliance on modular specialized subsystems and maximally expanding the combinatory possibilities. Following Dehaene (2009), a “neuronal workspace” emerges whose main function is to assemble, confront, *recombine, and synthesize knowledge.* This system is further endowed with a fringe of spontaneous fluctuation that allows for the testing of new ideas, related to both the emergence of reflexive consciousness and the human competence for cultural invention. Although conscious brain activity fluctuates stochastically it does not wander at random. Selection mechanisms stabilize the combinations of ideas that are most interesting, useful or just “contagious”: privileged neuronal projections coming from the evaluation and reward circuits of orbitofrontal and cingulate cortex as well as the subcortical nuclei of amygdala and the basal ganglia are participating in this process.

Therefore, in the extent to which those premises are correct, a compact approach to *knowledge automation and recombination* by the central nervous system seems achievable, and further, a new “Theory of Mind” could be contemplated. It will be close to current attempts on formulating a motor-centered epistemology, which has been deemed by relevant neuroscientists as one the best foundations for explaining our "automated cognition". See different expostulations about the organization of action and advanced cognition (Allman, 1999; Berthoz, 2000; Edelman & Tononi 2000; Arbib, 2001; Fuster, 2003; Changeux, 2004; Buzsáki, 2006; Dehaene, 2009; Nunez, 2010).

4. The Sciences

Is "recombination" too narrow a window when we enter into the organization of the social-cognitive dynamics? Not at all. Although we still lack adequate “theories of mind” to rely upon (as already said, a very unfortunate theoretical void), approaching science itself as a composite informational construction and particularly as *knowledge recombination* looks feasible.

We can quote from Brian Arthur (2009), in his recent approach to the nature of technological change, which is so close to the dynamics of science itself: *"Conventional thinking ascribes the invention of technologies to ‘thinking outside the box’, or vaguely to genius or creativity, but this book shows that such explanations are inadequate. Rather, technologies are put together from pieces — themselves technologies — that already exist. Technologies therefore share common ancestries and combine, morph, and combine again to create further technologies. Technology evolves much as a coral reef builds itself from activities of small organisms — it creates itself from itself; all technologies are descended from earlier technologies..."*

Mutatis mutandis, the recombination idea would apply to science as well. The “natural” division of work within scientific communities seems to reflect the presence of knowledge recombination processes: the need of specialized disciplines and the reliance on paradigms, the fracture and emergence of new fields, the systematic increase in the number of disciplines during last centuries, the clusters and citation networking structures within scientific publications... Disciplines, rather than being isolated fields, are continuously mixing and rearranging their contents, *recombining* them, for the sake of the problems they have to solve, and factually giving birth to successive generations of inter-disciplines (e.g., information-physics, physical chemistry, biophysics, biochemistry, bioenergetics, bioengineering, socio-physics, sociobiology, psycho-sociology, neuro-psychiatry, socio-information, etc.). However, the *recombination of knowledge* has passed almost unnoticed in traditional philosophy of science, notwithstanding the massive presence of the phenomenon in contemporary scientific-technological societies (Scott, 1998). It has been estimated that after the industrial revolution the number of scientific fields has doubled with each passing generation: during the last 30 years, the number has increased from around 3000 disciplines and sub-disciplines in the 70’s, to almost 7000 nowadays. Indeed, science has become too complex a system, and we badly need fresh theoretical new views on how societies create, use, and recombine such a number of fields of knowledge.

The way different disciplines “process” their specific information and create new knowledge, and keep it in record while at the same time this knowledge is widely disseminated so that it can be put into action, and again combined and recombined with elements of all the other disciplines, neatly becomes another information paradigm. Reliable knowledge mediates action/perception cycles of individuals and prolongs them, supra-individually, making possible a more cogent and integrated closure at the social scale. The social creation of knowledge paradigmatically becomes an informational process, ultimately derived from knowledge recombination processes in the cerebral “workspace” of individuals. We really see a “collective nervous system”, a “social workspace” in action. Indeed the “swarm intelligence” that emerges goes far beyond the perception and action capabilities of the limited individual. In point of fact, the strict conditions put by the scientific method are also efficient protocols that grant the social decomposability of problems (Rosen, 2000). The scientific method itself appears from this perspective as the conditions to be met for a coherent decomposition of problems by communities of problem-solvers whose workings are separated in time and space. Standards, measurements, mathematical operations, formalizations, and so on become ways and means to extrovert mental operations out of the individual’s nervous system and directly interconnect perceptions and actions at a vast institutional-social scale (Hobart & Schiffman, 1998). The success of science in this informational jumping over the individual's limitations has been rationalized as the superiority of the scientific method (leaving aside any communication and thought-collective aspects) or directly attributed to "*the unreasonable effectiveness of mathematics*" (Wigner, 1960). However, there is not much understanding of the underlying "informational" causes (Lanham, 2006; Wright, 2007).

In the same way that we have already developed philosophy of science, history of science, and psychology & sociology of science, we would also need a genuine informational approach to science. Otherwise global visions of the scientific enterprise will oscillate in between the mythical-parochial reductionism (Marijuán, 1996) and the bureaucratic pragmatism of "*seeing like a state*" (Scott, 1998). A well-developed information science should encourage a non-hierarchical relationship between the major disciplines, highlight their mutual interactions, and should also systematically promote the *knowledge recombination* processes, educating for a better and more "real" social usage of multidisciplinary knowledge. Information science should take full responsibility in advancing a new understanding on the integration mechanisms at work in the individuals' knowledge and a new view on the sciences themselves, which quite probably will be of importance for the future achievement of really sustainable, knowledge-based societies.

5. Evolutionary conclusions: from genomics to *scientomics*

It can be argued that the growth of informational complexity of cells, nervous systems, and societies along their respective evolutionary, ontogenetic, and historical trajectories has been based on the cumulative consequences of knowledge recombination phenomena. From the point of view of "natural computing" there could be some lessons to learn on how very limited "agents" are capable of developing a collective processing that goes far away from the computing bounds of each single agential entity, and that process includes relying on combinations of successful interactive memories of past experiences —knowledge recombination. The recognition of this commonality, however, has been obscured, among other causes, by the structural and dynamic heterogeneity of repositories in the different informational entities, and above all by being subject of quite separated clusters of scientific disciplines: molecular and evolutionary biology, cognitive neurodynamics, philosophy of science/"geography" of science. Seemingly, increased epistemic distance translates into more difficult and less frequent interrelation processes.

At the time being, putting into practical test the recombination idea might be achieved rather partially. There is insufficient development in the neurosciences yet about the set of concepts mentioned ("workspace", "behavioral-processual engine", "dark energy"). But there might be sufficient room to compare the biological evolution of DNA codes of protein domains and the social-historical evolution of scientific disciplinary contents. Do cognitive "modules" exist within disciplines that travel to other disciplines and generate new fields there? If so, could the "combinatory" processes in both realms be interrelated?

Culturomics might have already paved part of the way. Borrowing the main concepts and techniques from evolutionary biology, J.B. Michel & E.L. Aiden were able to track the growth, change, and decline of the most meaningful *published words* during last centuries (Michel et al. 2011). The new term they have coined, *culturomics*, means the application of "genomic techniques" of high-throughput data collection and analysis to the study of human culture, as sampled in a vast mapping of words from a corpus of digitized books, containing about 4% of all printed books ever published. Further sources might be incorporated to the culturomic stock:

newspapers, manuscripts, maps, artwork, etc. Analysis of this corpus enables a new qualitative and quantitative investigation of cultural trends, social and political influences, fashions, and all sort of cultural phenomena...

Thus, the knowledge recombination hypothesis applied to the historical evolution of science might be considered in *scientomic* terms, as an evolutionary quest on the combinatory activity of disciplinary modules or domains of theoretical-practical knowledge travelling to other disciplines and changing there the local textures of knowledge, altering the regional maps of science, and the whole complexion of the world of knowledge at large. In other words, influential modules such as Euclidian geometry, Newtonian mechanics, differential equations, genetics, and so on (and a multitude of other minor modules), would have generated the history of sciences, not only "developmentally" inside their own fields, but even more "combinatorially", propelling the multidisciplinary evolution and cross-fertilization among scientific disciplines. In terms of education science something similar would happen too, for an abridged recapitulation resembling Haeckel's law seems to be taking place in the ontogenetic development of an individual's knowledge, which somehow recapitulates the fundamentals of the social acquisition of knowledge along history.

Scientomics, which we are suggesting will be an important future task for the consolidation of information science, appears as a multidisciplinary research-project running in parallel to current achievements of culturomics in the cultural realm, though pointing at some more ambitious epistemic goals. Indeed the creation of a proficient *"scientomics"* new field would help to make sense of the historical processes of science, and of human knowledge in action.

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INFORMATION IN THE STRUCTURE OF THE WORLD

Mark Burgin

Abstract: Finding the place of information in the world is an important philosophical and methodological problem. Some authors relate information only to society. Others also include the level of individual human beings. In contrast to this, many presume that information is everywhere in nature. In this paper, we treat this problem, taking it at a different level of placing information in the structure of the world. Consequently, at first, we describe the global structure of the world and then find the place of information in this structure. In addition, we consider structure of information processes, as well as relations between information and basic constituents of the world, such as matter, energy, mentality and knowledge

Keywords: information, logic, operator, natural, society,

Introduction

Understanding importance of information, researchers began their quest in finding what information is, what the place of information in the world is, how to measure information and many other important theoretical, philosophical and methodological questions related to information. As Wiener wrote, "Information is information, not matter or energy."

Scientists and philosophers suggested dozens of definitions of information, infinite systems of measures of information and a diversity of opinions about the place of information in the world. Some authors relate information only to society. Other researchers also include the level of a separate individual. Some ascribe information only to people, while others relate it also to animals and other living beings. In contrast to this, many presume that information is everywhere in nature. In this paper, we treat this problem, taking it at a different level of placing information in the structure of the world. Consequently, at first, we describe the global structure of the world and then find the place of information in this structure. In addition, we consider structure of information processes, as well as relations between information and basic constituents of the world, such as matter, energy, mentality and knowledge.

In Section 1, we explicate the global structure of the world in the historical perspective, starting with the worldview of Plato and bringing it to our days. Section 2 determines the place of information in the global structure of the world and analyzes structures related to information processes. In Section 3, relations between information and knowledge are explained.

2. The Structure of the World

Plato was the first outstanding philosopher who elaborated and discussed a definite structure of the world. In his dialogues, Plato mostly discusses two worlds: the World of Ideas/Forms, which is perfect unchangeable and eternal, and the Material World, which is not real being an imperfect reflection of the World of Ideas/Forms. However, describing these worlds, he cannot leave without an answer the crucial question asking how people get knowledge about these worlds. Answers inevitably involve the third world - mentality of an individual. In his dialogue *The Republic*, Plato has Socrates explain the literary analogy of a *divided line* to teach basic philosophical ideas about levels of existence and the corresponding structure of the individual mentality. Going from the lowest part to the highest, the individual mentality contains: *imagination*, *senses*, *intelligence* (as logical thinking) and (philosophical) *intuition*. In such a way, it is possible to conclude that in the worldview of Plato, the world as whole included the Mental World as its constituent.

All three worlds assemble together as the *global world structure*. This triadic structure has an interesting history. In the light of contemporary knowledge, the first was the philosophical tradition that is given in Figure 1.

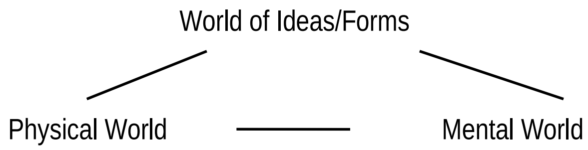

Figure 1. The Plato Triad of the world

According to physics, people live in the *physical* (*material*) *world* and this is the only reality that exists. In contrast to this opinion, subjective philosophies and religious teachings assert that only the mental world is real, while the physical world is just an appearance, a shadow without substance. For instance, Buddhism explains that the whole physical reality is a great illusion and the only reality is the spiritual world. In some forms of Buddhism (e.g., *Yogacara*), it is assumed that all things are created by Mind. At the same time, achievements of physics brought scientists to the edge of physical reality where extremely small physical objects, such as quarks or neutrons, and extremely large physical objects, such as our Universe as a whole, do not allow direct comprehensive observation. As a result, both extremities become more structures than material things. In this context, the outstanding physicist Max Born admits that the notion of reality in the physical world had become, during the last century, rather problematic [Born, 1953].

At the same time, science has enough evidence to admit reality of the *mental world*. As states contemporary psychology, each individual has a specific inner world, which forms mentality of the individual and is based on the psyche. However, there is a controversy whether individual mentality is a product of the person's organism (body), or more exactly, of the brain, or the individual mentality transcends the body. In any case, these individual inner worlds form the lowest level of the mental world, which complements our physical world. On the next level, there are mental worlds of groups of people, communities and the whole society. It is possible to develop this hierarchy of mental worlds but it is done elsewhere demonstrating that the mental world is different from the physical world and constitutes an important part of our reality.

Moreover, our mentality influences the *physical world* and can change it. We can see how ideas change our planet, create many new things and destroy existing ones. Even physicists, who study the very foundation of the physical world, developed the, so-called, observer-created reality interpretation of quantum phenomena. The prominent physicist, John Archibald Wheeler, suggests that in such a way it is possible to change even the past. He stresses [Wheeler, 1977] that phenomena on the level of subatomic particles are unreal until observed. Existence of the *physical world* and *mental world* brings us to a dualistic model of reality.

However, having no evidence for and clear understanding of the World of Ideas, many philosophers and scientists, starting with Aristotle, argue that the World of Ideas causes many problems. Where is this world of ideas and how do we make contact with it? What is an idea in this sense? How is it possible for our mind to have an interaction with the Platonic realm so that our brain state is altered by that experience? Plato and his followers have not provided convincing answers to these questions. Thus, in spite of the attractive character of this idea, the majority of scientists and philosophers believe that the world of ideas does not exist, because nobody has been able to find any positive evidence in support of it. The crucial argument of physicists is that the main methods of verification in modern science are observations and experiments, and nobody has been able to find this world by means of observations and experiments. Nevertheless, there are modern thinkers, such as philosopher Karl Raimund Popper, mathematician Kurt Gödel, and physicist Roger Penrose, who continue to believe that the world of ideas exists.

Starting with ideas of Plato, Popper tried to eliminate the incomprehensible World of Ideas/Forms [Popper, 1974; 1979] building his own triadic ontology of the world based on scientific ideas. It has two forms, which may be called general and pure.

In the pure form, Popper Triad consists of three parts/worlds:

World 1 consists of physical bodies, including microparticles, physical processes, physical energy and physical fields.

World 2 consists of thoughts, feelings, decisions, perceptions, observations, etc.

World 3 consists of abstract or intellectual products of the human mind, such as languages, tales, stories, contents of books and documents, scientific conjectures and theories, mathematical constructions, etc.

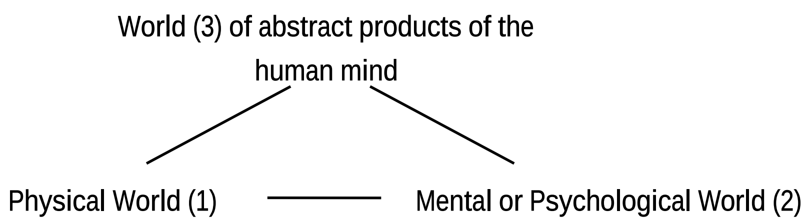

Figure 2. The Pure Popper Triad of the world

To define these worlds, Popper writes [Popper, 1976]:

"If we call the world of "things" or of physical objects - the first world, and the world of subjective experiences (such as thought processes) the second world, we may call the world of statements in themselves the third world. …

It would be easy ... to regard the whole of world 3 as timeless, as Plato suggested of his world of Forms or Ideas.... I propose a different view - one which, I have found, is surprisingly fruitful. I regard world 3 as being essentially the product of the human mind.... More precisely, I regard the world 3 of problems, theories, and critical arguments as one of the results of the evolution of human language, and as acting back on this evolution."

However, such an abstract nature of World 3 caused many questions about it real existence and Popper decided to extend it including other products of the human mind, such as books, paintings, sculptures, aeroplanes and other feats of engineering [Popper, 1978].

Thus, in the general form, Popper Triad consists of three parts/worlds:

World 1 consists of physical bodies, including microparticles, physical processes, physical energy and physical fields.

World 2 consists of thoughts, feelings, decisions, perceptions, observations, etc.

World 3 consists of all products of the human mind, such as books, paintings, sculptures, aeroplanes and other feats of engineering

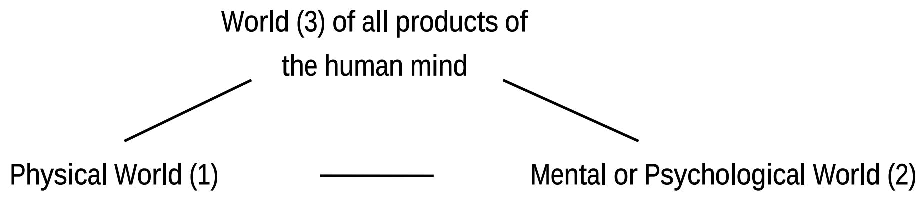

Figure 3. The General Popper Triad of the world

On the one hand, it is much easier to understand Popper Triad than the Plato Triad because products of the human mind are much more tangible than abstract ideas, which exist nobody knows where. On the other hand, there are phenomena related to products of the human mind, such as shapes and other features of physical objects, which are not included in the World 3 of Popper.

Other authors refer World 3 in the Popper Triad to signs in the sense of Charles Saunders Peirce although they do not insists that it consists of objects that Peirce would classify as signs (cf., for example, [Skagestad, 1993; Capuro and Hjorland, 2003]).

However, the progress of science and mathematics brought forth the discovery of the *world of structures* [Burgin, 1991; 1996; 1997], allowing the researchers to solve the mystery of the Plato Forms or Ideas. On the level of ideas, this world may be associated with the Platonic world of ideas or forms in the same way as atoms of modern physics may be related to the atoms of Democritus. In contrast to Plato, science has been able to prove existence of the world of structures, demonstrating by means of observations and experiments, that this world constitutes the structural level of the world as the whole. Each system, phenomenon, or process either in nature, technology or society has some structure. These structures exist like material things, such as tables, chairs, or buildings do, and form the *structural level* of the world. When it is necessary to learn or to create some system or process, it is done, as a rule, by means of knowledge of the corresponding structure. Structures determine the essence of things.

Only recently, modern science came to a new understanding of Plato ideas, representing the global world structure as the *Existential Triad* of the world (cf. Figure 4).

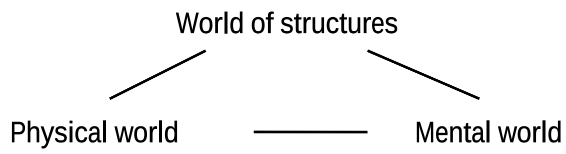

Figure 4. The Existential Triad of the world

In this triad, the Physical (material) World is interpreted as the physical reality studied by natural sciences, the Mental World encompasses different levels of mentality, and the World of Structures consists of various forms and types of structures. Each of these three worlds has a hierarchical structure with several levels or strata. For instance, the hierarchy of the physical world goes from subatomic particles to atoms to molecules to bodies to cells to living beings and so on.

The Plato Triad looks very similar to the Existential Triad as there is a direct correspondence between their vertices:

Material World ↔ Physical World

Mental World ↔ Mental World

World of Ideas/Forms ↔ World of Structures

So, it is important to understand what essential progress has been made from the time of Plato to our time and why these triads are similar and at the same time, fundamentally different.

Comparing the Material World of Plato and the Physical World from the Existential Triad, we see that on the ontological level, they are the same. However, on the epistemological (cognitive) level, they are basically different because due to the advancement of science, now people know much more about physical reality than at the time of Plato. It means that the known physical world from the Existential Triad is many times larger than the known material world from the Plato Triad. In addition, knowledge of the physical reality has become more exact and comprehensive.

Looking at the Mental World, we see that at the time of Plato, it included only individual mentality. Now science extended this picture and studies the Mental World on three levels, which are all included in the Existential Triad:

- The first level treats mentality of separate individuals and is the subject of psychological studies.
- The second level deals with group mentality of separate individuals and is the subject of social psychology.
- The third level encompasses of society as a whole and is the subject of social psychology.

Besides, the Mental World from the Existential Triad comprises higher (than the third) levels of mentality although they are not yet studied by science [Burgin, 1997; 2010].

It is necessary to remark that as physics does not study the physical reality as a whole but explores different parts and aspects of it, psychology also separates and investigates different parts and aspects of the mental reality, such as intelligence, emotions, or unconscious. As in the case of the Physical World, contemporary knowledge about the Mental World exceeds what was known by Plato and its contemporaries.

This is even truer for the World of Structures, which is much more understandable, exact and explored than the World of Ideas/Forms. When Plato and other adherents of the World of Ideas/Forms were asked what an idea or form was, they did not have a satisfactory answer. In contrast to this, many researchers have been analyzing and developing the concept of a structure [Ore, 1935; 1936; Bourbaki, 1948; 1957; 1960; Bucur and Deleanu, 1968; Corry, 1996; Burgin, 1997; Landry, 1999]. It is possible to find the most thorough analysis and the most advanced concept of a structure in [Burgin, 2010].

3 Information as a Basic Component of the World Structure

The place and the role of information in the world are defined by the ontological principles of the General Theory of Information, which is constructed as an axiomatic theory on three levels: *conceptual*, *methodological* (also called *meta-theoretical*) and *theoretical* [Burgin, 2010].

On the conceptual level, the essence of information as a dynamic object playing a pivotal role in all walks of reality is explicated, clarifying a quantity of misconceptions, fallacies and illusions.

Methodological (meta-theoretical) level is based on two classes of principles and their relations. The first class contains ontological principles, which bring to light general properties and regularities of information and its functioning. Principles from the second class explain how to measure information and are called axiological principles.

On the theoretical level, axioms of structures used and axioms reflecting features of information are introduced and utilized for building models of information and related phenomena, e.g., information flow or information processing. These models are used for studies of information and various related systems and phenomena, e.g., information flow in society or information processing systems, such as computers and networks.

To clarify the concept of information, we consider here the basic ontological principles. The first of them separates local and global approaches to information definition, i.e., in what context information is defined.

Ontological Principle O1 (the *Locality Principle*). It is necessary to separate information in general from information (or a portion of information) for a system *R*.

In other words, empirically, it is possible to speak only about information (or a portion of information) for a system.

The system *R* with respect to which some information is considered is called the *receiver*, *receptor* or *recipient* of this information.

Such a receiver/recipient can be a person, community, class of students, audience in a theater, animal, bird, fish, computer, network, database and so on.

The Locality Principle explicates an important property of information, but says nothing what information is. The essence of information is described by the second ontological principle, which has several forms.

Ontological Principle O2 (the *General Transformation Principle*). In a broad sense, *information* for a system *R* is a capacity to cause changes in the system *R*.

Thus, we may understand information in a broad sense as a capacity (ability or potency) of things, both material and abstract, to change other things. Information exists in the form of *portions of information*. Informally, a portion of information is such information that can be separated from other information. Information is, as a rule, about something. What information is about is called the *object* of this information.

The Ontological Principle O2 has several consequences.

- First, it demonstrates that information is closely connected to transformation. Namely, it means that information and transformation are functionally similar because they both point to changes in a system. At the same time, they are different because information is potency for (or in some sense, cause of) change, while transformation is the change itself, or in other words, transformation is an operation, while information is what induces this operation.
- Second, the Ontological Principle O2 explains *why* information influences society and individuals all the time, as well as why this influence grows with the development of society. Namely, reception of information by individuals and social groups induces transformation. In this sense, information is similar to energy. Moreover, according to the Ontological Principle O2, energy is a kind of information in a broad sense. This well correlates with the von Weizsäcker's idea that *energy might in the end turn out to be information* [Weizsäcker, 1974].
- Third, the Ontological Principle O2 makes it possible to separate different kinds of information. For instance, people, as well as any computer, have many kinds of memory. It is even supposed that each part of the brain has several types of memory agencies that work in somewhat different ways, to suit particular purposes. Thus, it is possible to consider each of these memory agencies as a separate system and to study differences between information that changes each type of memory. This might help to understand the interplay between stability and flexibility of mind, in general, and memory, in particular.

In essence, we can see that all kinds and types of information are encompassed by the Ontological Principle O2. In the most concise form, it is demonstrated in [Burgin, 2010].

However, 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, must be in significant accord with our common ways of thinking and talking about what the theory is about, else there is the danger that theory is not about what it purports to be about.

Information in a proper sense is defined of structural infological systems. In essence, any subsystem of a system may be considered as its infological system. However, information in a proper sense acts on structural infological systems. An infological system structural is structural if all its elements are structures. For example, systems of knowledge are structures.

To achieve precision in the information definition, we do two conceptual steps. At 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. That is why it is impossible and, as well as, counterproductive to give an exact and thus, too rigid and restricted definition of an infological system.

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 principle.

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*).

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 the infological system IF(*R*) are called *infological elements*. The nature of the infological elements depends on the nature of the infological system IF(*R*).

There is no exact definition of infological elements although there are various entities that are naturally considered as infological elements as they allow one to build theories of information that inherit 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 cognitive infological elements.

When we take a physical system *D* as the infological system and allow only for physical changes, information with respect to *D* coincides with energy.

Taking a mental system *B* as the infological system IF(*R*) and considering only mental changes, information with respect to *B* coincides with mental energy. In 1874, the concept of psychic energy, also called *psychological energy*, was developed in the field of psychodynamics by German scientist Ernst Wilhelm von Brücke who proposed that all living organisms are energy-systems governed by the principle of the conservation of energy. Later Sigmund Freud adopted this new idea about energy and suggested that it was possible to apply both the first law of thermodynamics and the second law of thermodynamics to mental processes, describing functioning of a mental or psychic energy (cf. [Freud, 1949]. In *The Ego and the Id*, Freud argued that the Id was the source of the personality's desires, and therefore of the psychic energy that powered the mind. The psychoanalytic approach assumes that the psyche of people needs some kind of energy to make it work. This energy is used in mental work, such as thinking, feeling, and remembering. It is assumed that psychic energy comes from the two main drives: Eros (or libido, the life and sexual instincts) and Thanatos (death instinct). The theory of psychic energy was further developed by Carl Gustav Jung, a student of Freud, who (in 1928) published a seminal essay entitled "On Psychic Energy" (cf. [Jung, 1969]). Later, the theory of psychodynamics and the concept of "psychic energy" was developed further by such well-known psychologists as Alfred Adler and Melanie Klein.

These ideas, which connect concepts of information and energy, are summarized in the following principle which defines information in the strict sense.

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 system 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 looks like it is possible to give an exact definition of a cognitive infological system. However, now cognitive sciences do not know all structural elements involved in cognition. A straightforward definition specifies cognition as 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.

In this context, the concept of information is considered on three basic levels of generality:

1. *Information in a broad sense* is considered when there are no restrictions on the infological system (cf. Ontological Principle O2).

2. *Information in the strict sense* is considered when the infological system consists of structural elements (cf. Ontological Principle O2a).

3. *Cognitive information* is considered when the infological system consists of cognitive structures, such as knowledge, beliefs, ideas, images, etc. (cf. Ontological Principle O2c).

As a result, we come to three levels of information understanding:

1. *Information in a broad sense* for a system *R* is a capability (potential) to change (transform) this system in any way.

2. *Information in the strict sense* for a system *R* is a capability (potential) to change (transform) structural components of this system, e.g., cognitive information changes knowledge of the system, affective information changes the state of the system, while effective information changes system orientation.

3. *Cognitive information* for a system *R* is a capability (potential) to change (transform) the cognitive subsystem of this system.

This information stratification allows us to place information in a broad sense as a pivotal essence in the world as whole and all its components. At the same time, information in a strict sense belongs to the World of Structures, playing there also a pivotal role and having its counterparts in two other Worlds.

This situation is represented by Figure 4. Cognitive information naturally belongs to the domain of cognitive systems.

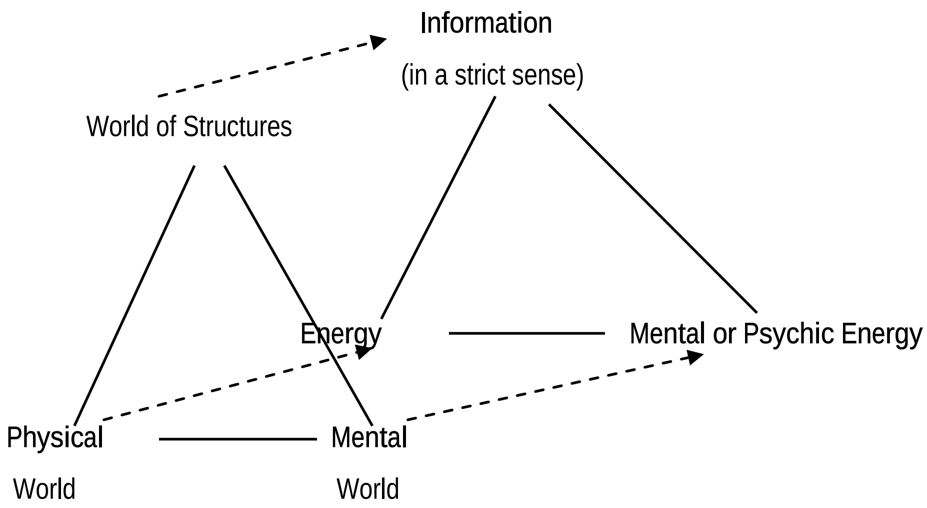

Figure 5. Information in the Structure of the World

It is interesting that defining information as "Information: that which determines form", MacKay also related it to the World of Structures [MacKay, 1969] because *forms* form a special kind of *structures* [Burgin, 2010].

For those who prefer to have a more exact definition of information contrary to a broader perspective, it is possible to define a cognitive infological system as the system of knowledge. This approach was used in [Shreider, 1967] and [Mizzaro, 2001].

Cognitive infological systems are standard examples of infological systems, while their elements, such as knowledge, data, images, ideas, fantasies, abstractions, and beliefs, are standard examples of infological elements. Cognitive infological systems are very important, especially, for intelligent systems as the majority of researchers believe that information is intrinsically connected to knowledge.

Ontological Principle O2c (the ***Cognitive Transformation Principle***). *Cognitive information* for a system *R*, is a capacity to cause changes in the cognitive infological system IFC(*R*) of the system *R*.

As the cognitive infological system contains knowledge of the system it belongs, cognitive information is the source of knowledge changes.

It is useful to understand that in the definition of cognitive information, as well as of other types of information in the strict sense, it is assumed that an infological system IF(*R*) of the system *R* is a part (subsystem) of the system *R*. However, people have always tried to extend their cognitive tools using different things from their environment. In ancient times, people made marks on stones and sticks. Then they used paper. Now they use computers and computer networks.

There are two ways to take this peculiarity into consideration. In one approach, it is suggested to consider *extended infological systems* that do not completely belong to the primary system *R* that receives information. For instance, taking an individual *A*, it is possible to include in the extended cognitive infological system IFC(*A*) of *A* not only the mind of *A* but also memory of the computer that *A* uses, books that *A* reads and cognitive objects used by *A*.

Another approach extends the primary system *R* as a cognitive object, including all objects used for cognitive purposes. In this case, when we regard an individual *A* as a cognitive system *R*, we have to include (in *R*) all cognitive tools used by *A*. The second approach does not demand to consider extended infological systems. In this case, all infological systems of *R* are parts (subsystems) of the primary system *R*.

Cognitive information belongs to the World of Cognitive Structures, such as knowledge, beliefs, idea, concepts, images, hypotheses, etc.

Information is a dynamic phenomenon. So, it is important to understand how it functions. This is explained by the Ontological Principles O3 – O5 and represented in Figures 6 - 11.

Ontological Principle O3 (the *Embodiment Principle*). *For any portion of information I, there is always a carrier C of this portion of information for a system R.*

This trait of information is represented in Figure 6.

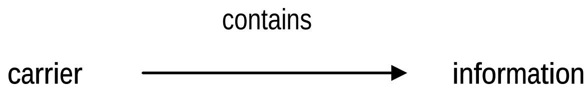

Figure 6. The information carrier triad

There are material carriers of information, such as the memory, DNA or a book, and there are structural carriers of information, such as a text, symbol or idea. A specific type of information carriers is formed by information representations.

Ontological Principle O4 (the *Representability Principle*). *For any portion of information I, there is always a representation C of this portion of information for a system R.*

As any information representation is, in some sense, its carrier the Ontological Principle O4 implies the Ontological Principle O3.

This trait of information is represented in Figure 7.

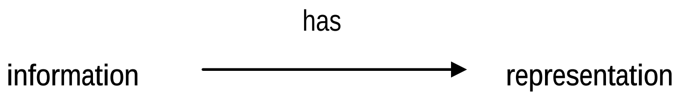

Figure 7. The information representation triad

The process of acquiring a material representation and/or material carrier is called materialization of information. For instance, an example of such materialization is the situation when a scientist has and idea and then writes this idea down or creates a file with a description of this idea. In a similar way, artists and sculptors materialize their vision in paintings and sculptures. Any person sending information finds a material representation or material carrier for this information, in such a way, performing information materialization. A general schema of materialization is studied in [Burgin and Markov, 1991].

People empirically observed that for information to become available, the carrier must interact with a receptor that was capable of detecting information the carrier contained. This empirical fact is represented by the following principle.

Ontological Principle O5 (the *Interaction Principle*). *A transaction / transition / transmission of information goes on only in some interaction of the carrier with the system*.

Different researchers wrote about this central trait of information (cf., for example, [Shannon, 1948; Ruben, 1992; Burgin, 1993; 1997; Markov, et al, 1993; 2003; 2006; Roederer, 2002]), which is represented in Figure 8.

channel

Source/Carrier ⟶ Receiver/Receptor/Recipient

Figure 8. The static communication triad

Interaction is also described by the following triad in the functional way.

message

Sender ⟶ Receiver/Receptor/Recipient

Figure 9. The functional communication triad

It is necessary to remark that interaction is a central trait but a defining property of information. Indeed, the Ontological Principle O2 and all its versions imply existence of three kinds of information: *potential*, *actualizing* and *actual* information. It is interesting that there are also three types of actualizing information: *emerging*, *becoming* and *virtual* information.

While triads from Figures 8 and 9 depict only transition of information or one-way communication, actual communication is an exchange of information and is described by the parallel composition of static or functional communication triads from Figures 8 and 9.

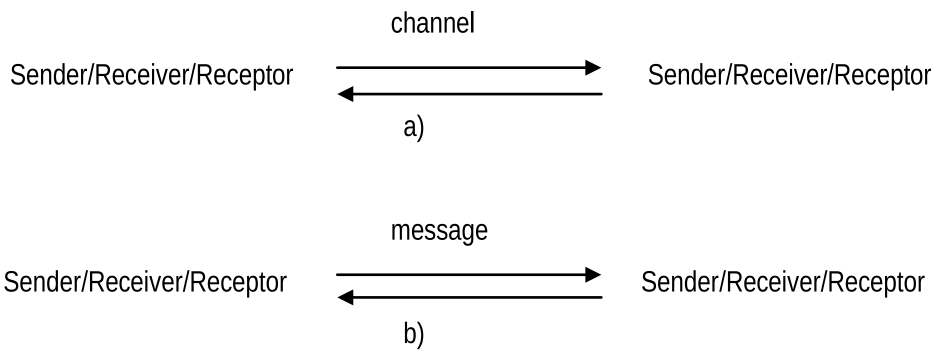

Figure 10. The two-way communication triads

One more communication triad is elaborated by Markov, et al, who write, “We may say that the *reflection* of the first entity in the second one is “*information”* for the first entity if there is corresponded reflection evidence” [Markov et al, 2003]. This gives us the following triad:

(source, recipient; evidence)

An extended form of this triad is given in Figure 11.

Figure 11. The Markov information triad

This triad forms a context for information processes and thus, for information itself. The third component of this triad is connected to a very important philosophical and methodological question in physics about the role of the observer in quantum reality [Wheeler, 1977]. Physicists ask the question whether the world or some events in it exist when nobody observes them. In a similar way, it is possible to ask a question whether information exists when there is no evidence about occurred interaction. Note that according to the general theory of information, information, namely, potential information, exists not only when there is no evidence about occurred interaction but even when there is no interaction at all.

4 Information and Knowledge

The Ontological Principle O2a implies that information is not of the same kind of essences as knowledge and data, which are structures [Burgin, 1997]. Although some researchers announce that information is a kind of data, while others claim that information is a kind of knowledge, from the scientific perspective, it is more efficient to treat information as an essence that has a different nature because other terms represent arious kinds of knowledge and information. Actually, if we take that *matter* is the name for all substances as opposed to *energy* and the *vacuum*, then relations represented in Figure 5 bring us to the Structure-Information-Matter-Energy (SIME) Square given in Figure 12.

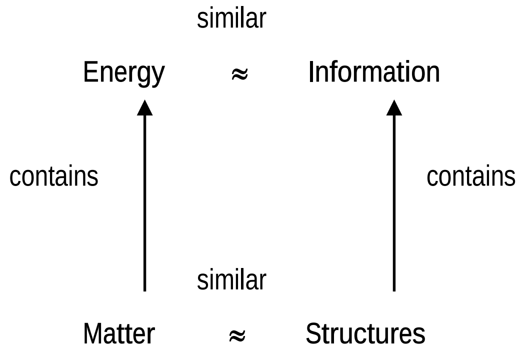

Figure 12. The Structure-Information-Matter-Energy (SIME) Square

In other words, we have the following principle:

Information is related to structures as energy is related to matter.

As knowledge and data are specific structures, Figure 12 is specialized into the Knowledge-Information-Matter-Energy (KIME) Square given in Figure 13.

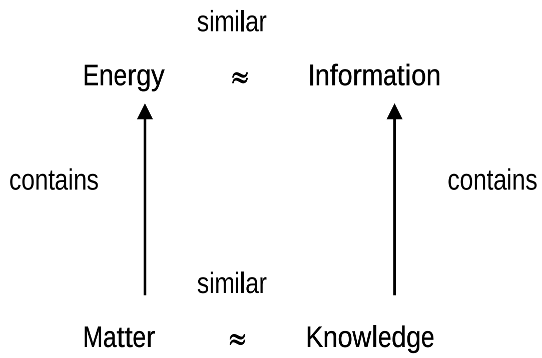

Figure 13. The Knowledge-Information-Matter-Energy (KIME) Square

Information also allows explications of relations between the physical reality and mental world. Indeed, all people, including scientists, get their knowledge about the physical reality only based on information that comes (is obtained) from physical objects. Even theoretical and philosophical considerations become knowledge the physical reality only when they are correlated with information that comes (is obtained) from physical objects. As a result, information becomes an intermediary, a connecting link between physical and mental. Consequently, we have the following Cartesian Triad, which shows how the physical reality is reflected in mental world (cf. Figure 14). It is called the Cartesian Triad because Descartes was the main proponent of the dualistic approach to reality, separating it into the Material World and the Mental World.

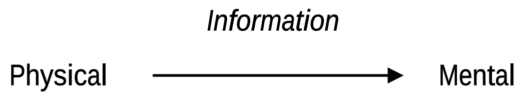

Figure 14. The Cartesian Triad

At the same time, the lower levels of mentality [Burgin, 1997; 2010] are based on physical systems: on the brain in the case of the individual mentality and people in the case of the group and social mentality. This results in following Materialistic Triad. It is called the Materialistic Triad because it reduces mentality to the physical level of nature. It is necessary to remark that many people assume that mentality is a virtually independent from the physical reality.

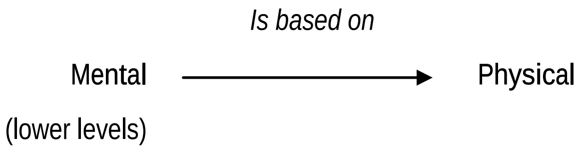

Figure 15. The Materialistic Triad

Including the SIME square into the global structure of the world, we come to the following structure of the Basic Components of the World. This structure is called the BC Prism and display the key structure of each of these components.

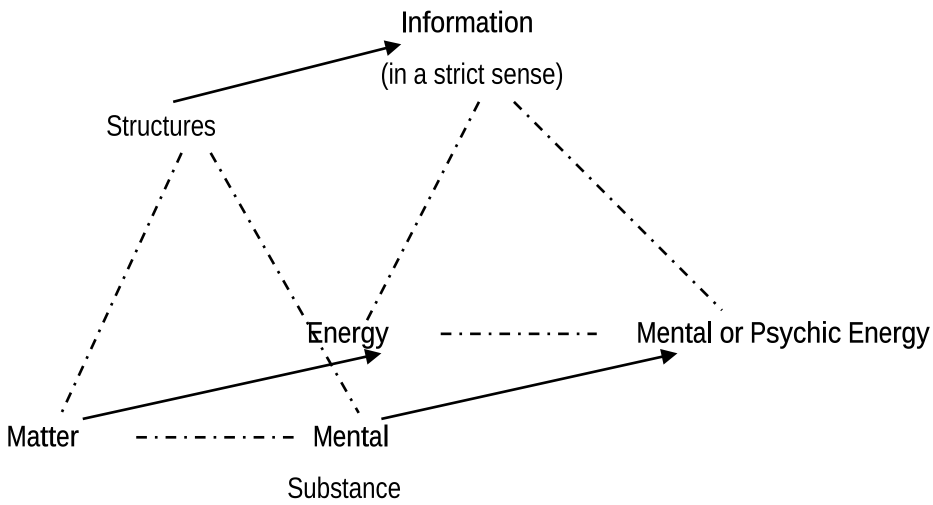

Figure 16. The Basic Components of the World in the form of the BC Prism

This shows that all three basic components of the world, the Physical World, Mental World and World of Structures, have a similar key structure, which is presented in Figure 17.

Substance → Information/Energy

Figure 17. The Key Structure of the World Components

5 Conclusion

The discussed description of relations between information and other basic entities places information the global structure of the world. At the same time, we know that there are different levels of reality (cf., for example, [Burgin, 1997; 2010]). For instance, there are levels of reality organized according to their dimensions, such as the level of subatomic particles, the level of atoms, the level of molecules, the level of physical objects in the same scale as a human being, the level of celestial bodies such as the Earth and other planets, the level of stars, the level of galaxies, etc. There are also organizational levels, such as the level of subatomic particles, the level of atoms, the level of molecules, the level of cells in a living organism, the level of organs in a living organism, the level of living organisms, the level of human beings, the level of society. Thus, the next step in the direction discussed in this paper is finding the place of information on different levels of reality.

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Areas of interest: Information, Complexity, Algorithms, Mathematics, Technology

INFORMATION AS A NATURAL AND SOCIAL OPERATOR

Joseph E. Brenner and Mark Burgin

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

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

Introduction

Rationale and Objective

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

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

Outline of the Paper

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

1 The Definition, Classification and Logic of Operators

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

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

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

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

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

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

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

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

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

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

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

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

1.1 Symbolic and Natural Operators

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

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

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

1.2 The Problem of Logic

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

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

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

2 THE LOGIC OF NATURAL OPERATORS

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

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

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

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

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

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

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

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

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

Figure 1. Process Change: LIR Non-Contradiction

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

Figure 2. Process Change: LIR Contradiction (Counteraction)

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

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

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

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

2.2 Natural Operators of the LIR Calculus

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

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

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

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

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

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

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

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

3 Information as a Natural Operator

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

3.1 Energy as Information

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

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

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

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

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

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

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

3.2 Information in Natural Objects and Processes. DNA and Evolution

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

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

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

3.3 Information and Self-Regulation

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

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

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

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

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

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

4 Information as a Social Operator

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

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

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

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

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

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

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

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

5 Operators and Theories of Information

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

5.1 Semantic Theories

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

Then we come to the following definition:

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

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

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

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

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

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

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

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

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

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

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

5.2 Semiotic Theories

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

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

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

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

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

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

5.3 Enformation

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

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

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

5.4 The Philosophy and Metaphilosophy of Information

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

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

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

Conclusion

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

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

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

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EMERGENT INFORMATION SOME SYSTEM-THEORETICAL CONSIDERATIONS ABOUT AN INTEGRATIVE INFORMATION CONCEPT

Wolfgang Hofkirchner

***Abstract**: Philosophy-of-information considerations can analyse information concepts according to four ways of thinking. A Unified Theory of Information (UTI) requires the fourth way of thinking – integration. This integration can be performed, if a complex systems view is informed by the heuristics of a historical and logical account. In particular, the terms of “difference” or “variety”, negentropy and semiosis are used for integration. Reference is made to Gregory Bateson, Arkady D. Ursul, Edgar Morin, and Charles Sanders Peirce. An integrated information definition is presented. Information is defined as relation such that an Evolutionary System s_e (signator; the signmaker) reflects (1) some perturbation P (signandum/signatum; (to-be-)signified (2) by the order O it builds up spontaneously (signans; the sign) (3) for the sake of negentropy. The process of information-generation coincides with the process of sign-production and both coincide with the process of self-organisation; so do their respective results: information, sign, and self-organised order. The concepts of self-organisation and information (sign) turn out to be co-extensive. The notion “emergent information” is applied to characterise the complexity of information processes that proceed between determinacy and indeterminacy. Since information generation is a process that allows novelty to emerge, it is worth noting that it is not a mechanical process that can be formalised, expressed by a mathematical function, or carried out by a computer.*

***Keywords**: Unified Theory of Information, Ways of Thinking, Difference, Variety, Negentropy, Semiosis, Indeterminacy, Reflection.*

Introduction

Philosophy-of-information considerations can analyse information concepts according to the way of thinking employed and show that there are, in principle, four ways of thinking in information [Hofkirchner 2011]: an objectivistic, materialistic and externalistic one which is reductionistic; two subjectivistic, idealistic and internalistic ones which are based on projectivism or disjunctivism; and a subject-object-dialectic, emergent-materialistic and perspectivistic one which aims at integration.

Starting from the conclusion that a Unified Theory of Information (UTI) requires an integrative concept of information, a historical and logical account of information is needed that might be defined as follows:

The meaning of the concept of information comprehends both what different manifestations of the phenomenon of information have in common and what is unique to them. Historical manifestations of information are descending from earlier manifestations but not deriving from them logically. With each historical manifestation that is to be conceived of, the concept of information is enriched by features not characteristic of it so far and extended so as to make the universal and the concrete unify in order to include the manifestation in the extension of the meaning (no concrete concept of information can be deduced from a more abstract concept but an abstract concept can be deduced from a more concrete one.)

The information concept wanted in a UTI is a concrete universal. Examples for concrete-universal concept scan be found not only in the biological classification of species but also in social sciences. An example of political economy is the development of capitalism. It's clear that this economic formation underwent several transformations (sometimes regarded as mutations into a different economic system that is not capitalist any more, but the reflection of the financial crisis that caused the current economic crises brought those speculations back down to earth). E.g., the following events have been argued in favour of transformations within capitalism: the development from free competition towards monopolies, the development of a close relationship between nation states and national monopolies, the development of transnational corporations, the development of the preponderance of financial capital over industrial capital in the course of globalisation and informatisation. Each development was, in a way, unpredicted and deemed to modify the "essence" of capitalist principles but not replace it fully. It might characterise a new stage in the evolution of capitalism, as the latest notions of "global capitalism" and "informational capitalism" insinuate.

Information as a difference that makes a difference

The philosophy-of-information considerations above are useful to inform cross-disciplinary, system-theoretical and complexity-oriented approaches toward an answer to the question of which place information has in the universe and which role creativity plays. It is argued that information has to, and can, be understood within the framework of self-organising systems.

According to a quote of G. Bateson which advanced to his famous definition of information, information is "a difference that makes a difference" [1973, p. 428]. This saying might be explicated like that: we can speak of information, if there is a difference in the environment of a self-organising system (the objective aspect) that makes a difference to this very system (the subjective aspect); a difference in the environment might be instantiated by an event or an entity and the difference that is made to the system might manifest itself as a change in its structure, state or behaviour which might be observed.

Russian philosopher of information A. D. Ursul had highlighted the intrinsic connection between information and difference in a similar manner. He had used the notion of "variety" that plays an important role in W. Ross Ashby's cybernetic theory – the Law of Requisite Variety states that a system is dynamically stable if its variety (number of states), i.e. the variety of its control mechanism, is greater than or equal to the variety of (the input from) another system, i.e. the variety of a system to be controlled. Ursul had defined information as "reflected variety" [1970, 166, 214 – translation W.H.]; information depends on variety and reflection: it is "variety that one object contains from another object" [1970, 166 –translation W.H.], "variety that is contained in an object in relation to another object (as result of their interaction)" [1970, 214 –translation W.H.].

Now we have to be aware of the fact that self-organisation itself is due to objective and subjective factors as well, as the following definition reminds us [Halley and Winkler 2008, 12]: "Self-organization is a dissipative nonequilibrium order at macroscopic levels, because of collective, nonlinear interactions between multiple microscopic components. This order is induced by interplay between intrinsic and extrinsic factors, and decays upon removal of the energy source. In this context, microscopic and macroscopic are relative."

Then we can conclude that the very process of self-organisation fulfils the interpretation of Bateson's definition given above as well as the definition of information by Ursul. For self-organisation refers to an event or an entity in the environment of the system which represents a difference out there and it is a creative activity of the system in the course of which novelty is produced in its structure, state or behaviour that is related to the difference out there and marks a difference in the development of the system. In that vein, self-organising systems display information generativity. In each self-organisation process information is produced.

Information as negentropic factor

Furthermore, self-organisation is a negentropic process because order is produced by it and the production of order is, by definition, a negentropic process. What then makes a difference for a system is whether or not a difference out there, variety out there, can be functionalised by the system for its negentropic process of building up order. Thus information is intrinsically connected to negentropy and organisation, as pointed out by French philosopher and sociologist E. Morin [1992, 350]: “Information is what allows negentropy to regenerate organization which allows information to regenerate negentropy.” Or [368]: “Information is what, starting from an engram or sign, allows negentropy to generate or regenerate negentropy on contact, in the framework or at the heart of an ad hoc negentropic organization.”

So information is functional for the system’s organisation. Negentropy is the grounds for the end-directedness of self-organisation which manifests itself in different kinds. E. Mayr [1974] distinguished between “teleomatic”, “teleonomic”, and “teleological” processes; the first evoke an analogy to automatic, and the second an analogy to economic processes. According to Mayr, teleomatic processes end up in an end as a consequence of physical laws like in gravity, entropy decay, reaction gradients. Processes are teleonomic due to an in-built programme which directs them towards an end like in homeostasis, ontogeny, biotic reproduction. Teleological processes can be found with the intervention of cognitive mechanisms, mostly human.

With Mayr teleomatic processes are strictly mechanical, that is, they can be described and explained in terms of strict determinism. But with the new paradigm it became apparent that there are more interesting systems than pure mechanical systems and these are self-organising systems. With them there is an end to which these systems tend, it is, in a way, implicit and internal, but its conditions for satisfaction depend almost wholly on external conditions. It is proposed here to reserve the category of teleomatic for processes in these primitive, physical and chemical, self-organising systems only (with Bénard convection cells or the Belousov-Zhabotinsky reaction waves as most prominent examples, see e.g. [Bishop 2008]).

Teleonomic systems go beyond mere teleomatic ones in that, to a certain degree, they can exert control over the conditions for meeting an end which itself is being built into them or, at least, given from the outside to them [Coulter et al. 1982, 43]. Since survival is an end that is being built-in to all living systems, all living systems manifest teleonomic processes.

And another step is the additional capability of setting goals, of constructing ends by the systems in question. We propose to reserve this capability for human systems only and to use the term “teleological” for them exclusively.

Since self-organising systems are end-directed, information for them is what contributes to their end.

Information as sign production

There is a another feature that neatly fits in the overall picture. Semiotics stresses the arbitrariness of signs produced. Because an object is something that is subject to mere determination by something else and a subject is something that objects to mere determination by something else, the generation of information is tantamount with drawing a self-made distinction by the irreproducible, irreversible, irreducible, unpredictable build-up of order during the process of self-organisation.

In semiotics signs are fundamentally defined as relationships. As an example, triadic semiotics in the tradition of C. S. Peirce [1983 and 2000] knows the "representamen" (the sign in a narrow sense as some kind of carrier), the "interpretant" (which means the "meaning" of the representamen and is not to be mixed up with an interpreter), and the "object", which altogether form the so-called semiotic triangle.

Recalling the subject-object dialectical cycle, we have to take into consideration that a subject never relates directly to an object. Its relation to the object is always mediated. It construes the means of mediation. In the course of the subject's acting upon the object the subject gives rise to something new by which it mediates itself with the object – the sign. The sign is a means for the subject to bring together its appetence for the object, that is, the signification it attributes to the object, with the affordance of the object, that is, the significance the object has for the subject. The appearance of the sign (*signans*) turns the subject into a signmaker (*signator*); the signification process (*significatio*) into a designation process (*designatio*) which means that the signification process is sign-mediated; and the object into a something (to be) signified (*signandum/signatum*) that bears a significance for the subject (*significantia*).

Hence a different semiotic triangle is the result. When the *signator* relates to the *signandum*, the *signator* generates the *signans* – this is an information process by which an information structure emerges; when the *signans* has emerged, the *signator* relates to the *signatum* only by utilising the *signans* – an information process in which the information structure exerts some dominance. The signification-significance relation between the system and the perturbation is duplicated, becomes independent, gets a life of its own, when becoming reified in the sign and thus upgraded to a tripartite relationship.

Thus the process of information-generation coincides with the process of sign-production and both coincide with the process of self-organisation; so do their respective results: information, sign, and self-organised order. The concepts of self-organisation and information (sign) turn out to be co-extensive.

Putting all three aspects discussed so far together, we can term information "emergent". On the one hand, information generation as constructing signs is due to the creativity of the self-organised system and thus part of spontaneity. On the other hand, it is in the service of contributing to negentropy, which would testify information as deterministic. Therefore it is right to state that information combines indeterminacy and determinacy. Emergence is always a combination of these.

Information definition

Self-organisation stands at the beginning of all information, insofar as the system selects one of a number of possible responses to a causal event in its environment; as it shows preference for the particular option it chooses to realise over a number of other options; as it decides to discriminate.

So we can say: information is involved in self-organisation. Every system acts and reacts in a network of systems, elements and networks, and is exposed to influences mediated by matter and/or energy relations. If the effects on the system are fully derivable from, and fully reducible to, the causes outside the system, no informational aspects can be separated from matter/energy cause-effect relations. However, as soon as the effects become dependent on the system as well (because the system itself contributes to them), as soon as the influences play the role of mere triggers for effects being self-organised by the system, as soon as degrees of freedom intervene and the reaction of the system is unequal to the action it undergoes, the system produces information (see Haken [1988]). Information is created, if there is a surplus of effects exceeding causes in a system. Information occurs during the process in which the system exhibits changes in its structure, or in its state, or in its behaviour [Fenzl and Hofkirchner 1997], i.e., changes which are due to the system. Information is created by a system, if it is organising itself at any level.

To distinguish this kind of self-organised, informational reaction (emergent) from a reaction of the stimulus-response type (mechanical) the term “reflection” shall be reintroduced but not in the sense of a naïve realism. “Reflection” as it is meant here does not comprise mechanical mirroring but deliberation on the human level along with all informational processes and their results on nonmechanical prehuman levels. This is quite in the sense of the German term “Widerspiegelung” which in the Hegel-Marx’s tradition was a dialectical one and, as the philosophical writings of Vladimir I. Lenin tried to insinuate, could and should be considered a fundamental property of all matter [1977, 53]. It’s a reflective universe we’re living in – a universe made up of reflective systems, more and more reflecting the universe (hence the idea that the universe, in the guise of human systems, comes to reflect itself).

In a figurative sense, information can be looked upon as the result of this process, as what is new in the structure, state, or behaviour. And insofar as this new feature in system A may serve to stimulate self-organising (and therefore informational) processes to produce new features in system B, we can speak of information in a metaphoric sense as if it were something to be sent from one system to another.

We can define information in terms of evolutionary systems theory as follows:

Information = def. relation such that an Evolutionary System s_e (*signator*; the signmaker) reflects

(1) some perturbation P (*signandum/signatum*; (to-be-)signified

(2) by the order O it builds up spontaneously (*signans*; the sign)

(3) for the sake of negentropy.

Conclusion

Summing up, we can speak of information in the following situations: where the deterministic connection between cause and effect is broken up; where a system‘s own activity comes into play, and the cause becomes the mere trigger of self-determined processes in the system, which finally lead to the effect; where the system makes a decision and a possibility is realised by an irreducible choice.

Actually, with the paradigm shift from the mechanistic worldview cognisant of objects only towards a more inclusive view of a less-than-strict, emergent, and even creative universe inhabited by subjects too, we have got everything required to connect the notion of information to the idea of self-organisation; it is the very idea of systems intervening between input/cause and output/effect and thus breaking up the direct cause-effect-relationships of the mechanistic worldview that facilitates, if not demands, the notion of information, for information is bound to the precondition of subjects and their subjective agency. Self-organising systems that transform the input into an output in a non-mechanical way, that is, in the context of an amount of degrees of freedom undeniably greater than that of a one-option only, are subjects. And each activity in such a context, each acting *vis-à-vis* undeniable degrees of freedom, is nothing less than the generation of information because the act to discriminate, to distinguish, to differentiate, is information.

Since information generation is a process that allows novelty to emerge, it is worth noting that it is not a mechanical process that can be formalised, expressed by a mathematical function, or carried out by a computer.

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FROM PHILOSOPHY TO THEORY OF INFORMATION

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Abstract: *This is an attempt to develop a systematic formal theory of information based on philosophical foundations adequate for the broad context of pre-systematic concept of information. The existing formalisms, in particular that commonly called information theory, consider only some aspects of information, such as its measure. In spite of spectacular successes of Shannon's entropy and its generalizations, the quantitative description did not help in the development of the formal description of the concept of information itself. In this paper, the brief review of the contexts in which the term information is being used is followed by similarly brief presentation of philosophical foundations incorporating such aspects of information as its selective and structural manifestations, information integration and semantics of information presented in more extensive form in other publications of the author. Finally, based on these foundations, a mathematical formalism is proposed with an explanation of its relationship to the philosophical concepts associated with information. The formalism utilizing mathematical concepts from the theory of closure spaces and associated with them complete lattices of closed subsets playing the role of generalized logic of information is taking into consideration the selective and structural manifestations of information. Since the original source of inspiration in the development of the formalism was in quantum logics, an outline of concepts in this domain is included in the appendix.*

Keywords: *Theory of information; Philosophy of information; Selective and structural information; Information integration; Semantics of information;*

ACM Classification Keywords: *H.1.1 Systems and Information Theory – Information Theory*

Introduction

Development of every systematic theory of a concept such as information requires some philosophical foundations and practical experience in dealing with this concept at a pre-systematic level. The latter includes in the case of information its quantitative characteristics in the process of information transmission provided by Claude E. Shannon's entropy and its subsequent generalizations, and the analysis of manipulation of information in the process of computing initiated by Alan Turing [Shannon, 1949; Turing, 1936].

Philosophical foundations for the theory should take into consideration other concepts which have been used to build the contexts in which reference has been made to the concept in question in order to reflect all already accumulated knowledge in the conceptual framework for the theory. For instance, the context for Shannon's entropy has been built by the probability theory, in particular probability distribution involved in the formula for entropy. Turing's analysis of computation is dependent on the idea of a state (of the processing unit, e.g. human computer or the machine, but indirectly also of the tape) and of its change. Neither of the original sources of the study of information have provided description of information or introduced its structural analysis. Shannon's entropy has been simply declared as a measure of information. Similarly, computation has been commonly called information processing, but both references to information have only character of interpretation going beyond the actual formal consideration. If we want to utilize the experience of these two domains, before a systematic theory of information is formulated, we have to find sufficiently broad conceptual framework which allows for consideration of the role of the concepts of a probability distribution and of a state.

It does not mean that the systematic theory has to repeat all conclusions of the studies made at the pre-systematic level, but that its philosophical foundations should allow for the reflection on advantages and disadvantages of the earlier results. The importance of the systematic approach is just in providing tools for the critical analysis of the concept as it was used in multiple contexts. In the case of information, there are many points where the earlier studies show weakness, such as apparent irrelevance of the meaning of information, and its theory should be able to overcome at least some of the earlier problems.

In the present paper, there is an attempt to select suitable philosophical foundations grounded in the broad range of contexts of the pre-systematic concept of information, and to propose a formalism which can be used for the purpose of the development of genuine theory of information.

Contexts of Information

The main two contexts of the pre-systematic concept of information have been already mentioned above together with their deficiencies for playing the role of theory of information, in particular their dissociation from meaning. Shannon's information theory has been criticized by the authors of attempts to develop semantic theories of information [Bar-Hillel & Carnap, 1952/1964], but these attempts have been no more successful in developing semantics of information, nor in formulation of adequate theory of information, than the orthodox approach.

It is not only that the measures of information, entropy or its generalizations do not refer to the meaning. More serious problem is that measuring information in terms of entropy seems inconsistent with the intuitive meaning of meaning. Even when we talk about information in a message, we construct the measure of information by the sum of entropy values for characters, while characters are units of the message below the level where we can talk about meaning. One character message is carrying measurable information, while in many languages it cannot have any meaning. Of course, we can introduce some meaning to one character by a new convention, but it is completely independent from the value of entropy.

Suppose we should avoid association of meaning with information. In the orthodox studies of information explicitly declaring irrelevance of the meaning for its goals there are frequent references to information as a reduction of uncertainty. How can meaningless information reduce uncertainty? If for instance it is understood that one character message, when arrives, is reducing uncertainty regarding which character would arrive, we are saying that it does not matter which character arrives, as the entropy is the same. But if it does not matter which character arrives, where is this uncertainty? Thus, it is not an issue *which* character arrives, but *that* a character is arriving. Thus, in such understanding each character of the alphabet is carrying the same information.

Sometimes, in the context of transmission of the one character message the measure of information is applied not to a message, but separately to each of the characters of the alphabet (as the logarithm with base two of the inverse of its probability) and entropy is interpreted as the mean value of measures for all characters. Here of course, we have clear reference to the meaning of the message, but meaning understood as the choice of a letter. Each letter automatically has different meaning. However, this is not what we understand by meaning of the language. If you do not know given language, you can access all letters of the message without knowing its meaning at all.

It is not much better in algorithmic information theory which has been developed by Andrey Nikolaevich Kolmogorov and independently by Gregory Chaitin within the framework of Turing machines. Here we have a curious result which tells us that the greatest measure of information is in random sequences of symbols. Even worse, we have the same algorithmic measure of information (the length of the shortest sequence of characters between its first left and first right non-blanks which produces the sequence under consideration in the process of computation) for sequences of different length and therefore of different entropy. The close relationship between the expected value of complexity measure for some special probability distributions and entropy which seems to connect the two measures from the perspective of algorithmic complexity theory [Li & Vitányi, 2008] does not mend the conceptual distinction. When in Shannon's approach the measure of information in a message is associated with the number of characters and the probability distribution of the selection of particular type of characters, algorithmic complexity is being derived from the structural characteristics of a sequence of characters based on the interaction between the states of the processing unit and that of the sequence.

At first, we could suspect that the algorithmic complexity may better reflect the meaning of information encoded in a sequence of characters, as it depends on the structural characteristics of the sequence. But actually, it tells us only about equivalence between sequences which does not even have to preserve the meaning sometimes associated with such sequences. For instance, if we use as a tape for Turing machine a message encoded in Morse alphabet with zero and one characters and run the machine, the meaning of the message most likely would be lost. Of course, there could be meaning of different type which can be preserved in the process of calculation, but there is no obvious way to find it.

Obviously, someone could say that the meaning and measure of information are two completely independent characteristics of the same entity. But then, what is the value of such measure for our understanding information? What actually is being measured? Moreover, we can find example showing that the same mathematical instrument, probability distribution of characters in the language, which determines the value of entropy (and all its generalizations) is a fundamental cryptographic tool (frequency analysis) for decryption of ciphers, i.e. for finding their meaning. It is true, that the knowledge of the value of entropy is not sufficient for decryption, we need all probability distribution, but we cannot expect complete independence of the meaning and measure of information.

While the algorithmic theory of complexity is clearly interested in the structural characteristics of information understood as sequences of characters, in Shannon's approach this interest is much less obvious. It can be seen in his interest in the description of messages in terms of probability distributions of subsequences (doubles, triples, etc.). What is common for both approaches, it is the assumption that the complexity or measure of information is related to the principle of linearity which requires that simpler units are put in a sequence to form units of higher rank. Certainly, it is a consequence of the original source of information studies in natural or artificial languages. The difference is in the fact, that implementation of the computing information systems related to algorithmic complexity theory involves propositional logic, while logical considerations in Shannon's approach are present only in the use of probability theory. However, it is clear that the study of information requires some involvement of logical or grammatical considerations, but in a generalized form appropriate for the level of generality transcending that of natural or artificial languages.

Thus far only the two main approaches to the study of the information related matters which have assumed paradigmatic role in science have been taken into account in reviewing the context for the concept of information.

However, the context is much wider. For the purpose of this article only three themes out of many in the disciplines which influenced the common sense view of information in the highest degree will be mentioned here.

The first is physics. Shannon hesitated to associate his measure of information with physics in spite of the decision to borrow the name of the measure of information from physical magnitude described by the same formula (if we disregard Boltzmann's constant). However, in time information was becoming increasingly "physical" [Szilard, 1929/1983; Schrödinger, 1945; Brillouin, 1956; Landauer, 1991, 1998] to end up in the view of many physicists as a concept of equally or even more fundamental character than matter and energy [Wheeler, 1990]. In addition to bringing the physical theories into the context of information, its study has been enriched by new ideas of quantum theoretical form of information and computation. The intuitive association of information with the state of its carrier has been formalized due to the fact that the state in quantum mechanics is described by probability distribution, which in turn is the key concept in the construction of the measures of information. Even more important was the fact that the probability measures in quantum theory are defined on a more general structure than the Boolean algebra of sets.

The second theme belonging to biology had its source in the question about genetic inheritance, but in some sense has been already present in the discussion of the meaning and origin of life for long time. The study of biological inheritance has been influenced by the same small book "What is Life?" written by Erwin Schrödinger [Schrödinger, 1945], which made information a subject of interest for physics. Its reading prompted Francis Crick to move his scientific interests from physics to molecular biology, which ultimately led to cooperation with James Watson, the discovery of the structure of DNA and the mechanism of information transfer in living material. Genetics is not the only chapter of biology in which information plays crucial role. If we combine two concepts, of information and structural organization, we could say that all biology and evolution theory are about explanation of life in their terms, although not all biologists link their discipline with information as close as François Jacob [Jacob, 1973]. Biology could add to the physical point of view the need for explanation of the high level of organization and integration of information observed in living organisms, which in the past was interpreted in the form of the vitalism as a categorically different status of living matter and more recently as emergentism [Schultz, 1998; Emmesche, 2001].

The third theme is the study of cognitive processes in terms of information processing in the brain. It started from the work of W. S. McCulloh and W. H. Pitts [McCulloh & Pitts, 1943] and has been accelerated by the contributions of the authors of great authority [Wiener, 1948; von Neumann, 1951] leading through the times of great hope for the ultimate resolution of the mysteries of the brain in terms of artificial neural networks to the attempts of utilizing quantum mechanical description. Although the hope for explanation of consciousness in the distributive form of neural networks and integrated form of quantum mechanical mechanism has not been justified by the actual outcomes, information has become the key concept in the studies of cognition and consciousness. The latter has been even identified with the integrated information in one of the most active research programs [Tononi & Edelman, 1998a,b; Velmans & Schneider, 2007].

Thus, the context for the development of philosophical foundations which can serve as the point of departure for the systematic theoretical approach to information includes such concepts as a system (at different levels of organization or integration), its state, symbol and meaning, measure of information and its relationship with probability distribution, integration of information, selective and structural information, ontological status of information and its relationship to matter and energy, its relationship to consciousness and cognition.

In this paper, due to limitation of its scope, not all elements of the context are directly involved in the presentation of the philosophical foundations and the theoretical framework. However, they have been analyzed in more extensive way in the other papers of the author listed in references.

Philosophical Foundations

The main objective of this paper is to present a formal theoretical model of information based on the particular choice of philosophical foundations for the concept of information proposed by the author in the earlier articles. To make the article self-contained an outline of these foundations is included below together with brief references to some of the concepts from the context of information described above. More extensive explanation can be found elsewhere [Schroeder, 2005, 2009].

The approach is built upon the very old philosophical tradition of the reflection on the relationship between unity and variety (one-many opposition). Information is understood here in this conceptual philosophical framework as an identification of the variety i.e. that which makes one out of the many (or creates unity out of variety). It presupposes some variety (many) which can be identified as a carrier of information, and some form of unity (one) which is predicated of this variety. Since the relationship (opposition) of one to many is relative, so is the concept of information understood this way.

There are two most basic ways the many can be made one, by a selection of one out of many (selective manifestation of information) or by a structure introduced in the many which unites it into a whole (structural manifestation of information). These are two complementary manifestations of information, not separate types of information, as either of them requires the presence of the other, although possibly with respect to a different information carrier, i.e. different variety. If the elements of the variety are devoid any structure, it is difficult to expect any information involved in the selection of one of them. The selection of one out of many is purely random. On the other hand, every particular structure imposed on the elements of the variety can be considered an outcome of the selection of one of a variety of possible structures. In the first case, the original variety of the elements is different from the variety formed by the structural subcomponents of each of the elements. In the latter case, the original variety of elements bound into a structure is different from the variety of potential structures. So the transition between different manifestations of information requires a change of the information carrier.

As a consequence of this understanding of information, there are two its main characteristics. One is quantitative, referring to the selective manifestation. If the selection of one out of many can be described by probability distribution, a measure of information reflecting the size of the variety and the level of determination of the selection can be the familiar entropy of Shannon which in the finite case is given by formula (1):

$$H(n,p) = -\sum p_i \log_2(p_i), \quad \sum p_i = 1, \quad \text{for } i=1,2,\ldots,n. \qquad (1)$$

or, to be consistent with the definition considered above, rather the alternative, but closely related measure given by formula (2) advocated by the author [Schroeder, 2004]:

$$Inf(n,p) = H(n,max) - H(n,p) = \sum p_i \log_2(np_i), \quad \sum p_i = 1, \quad \text{for } i=1,2,\ldots,n. \qquad (2)$$

It should be observed that the use of probability theory or the mathematical formula for the measure does not constitute any choice of the formal concept of information. It does not give us any knowledge of the properties (qualities) of information. Also, we have to remember that the measure can be introduced under the condition that a probability distribution describing the selection has been already defined, which not for all instances of information is possible.

The other is qualitative characteristic (but possibly admitting a quantitative form) referring to the structural manifestation, of a level of information integration which reflects the mutual interdependence of the elements of a variety [Schroeder, 2009]. This characteristic has been derived by the author from the formalism of quantum theory and within the more general philosophical considerations can be understood as indecomposability of the structure of the variety into independent components.

Before we will proceed to the formalization of the concept of information, a few further philosophically significant concepts will be presented. First of them is a concept of an information system which divides information carrier into portions of completely integrated information which can be identified with the identities of objects, and non-integrated information which can be identified with the states of the objects and their relations. Risking possible confusion, this division can be compared to the distinction between the essential and accidental properties of objects in Aristotelian philosophy. However, here objects do not possess properties or participate in them, but they are constituted by information in its integrated form. It is important to observe that this view is not necessarily leading to transcendental philosophical position. We can assume that information has epistemological status, consider identity of objects as different from “things as they are” and continue further reflection about the relationship (e.g. causal) between an object as it is and the integrated information constituting its identity, or we can stop at this point and assume that there is nothing beyond information integrated into identities of objects.

The second philosophical concept important for the context of the presented here theory of information is that of symbol and its meaning. It seems quite clear that symbolic relationship between a sign and its meaning appeared in the process of humanization of the ancestors of modern humans. In the view of the author it was a way to overcome the limitations of information processing in the brain which even now do not allow for handling more than about seven items at a time, which gave the title to the famous paper of George Miller “The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information.” [Miller, 1956/1994]. Most likely the magic is in the number three, as the number of seven objects gives us a variety of the size eight, when we remember that our brain has to handle the case of the absence of any items, and these eight choices require three bits of information. In any case, one of possible solutions to the limitation was a process of information nesting, which requires that the system carrying big volume of information is replaced in the processing by a system with much smaller volume. Thus, symbol is not pointing from a word (information unit) to its meaning (object of different ontological status,) but from an information system of small volume to one of a big volume. Therefore, in such understanding of symbolic representation it is a purely informational relationship. Someone committed to the position of the epistemological status of information can associate the meaning of information as described above (i.e. the information system represented by the symbol) with an interpretant in the tripartite approach of Peirce, but in the opinion of the author, it does not help at all in the understanding of the function of a symbol in which “object as it is” does not participate at all.

Summarizing, little bit more formally we could think about the relationship between a symbol and its denotation as a relationship between two information systems such that we have a correspondence between the identities of objects and a parallel relationship between their states.

Formalism for the Theory of Information

Now we can proceed to the formalization of the concept of information in reference to the philosophical definition of information as that which gives the unity to a variety. Thus the starting point could be to associate a set S with the variety and to consider simply the relationship resulting from set membership: $x \in S$. Although the membership in set S is determined by some (informally understood) information characterizing these and only these elements which belong to S, but it may have many different forms, for instance by a property predicated about x, or simply by listing of elements. Also, it would describe only the selective manifestation of information.

The set S may have, and usually actually does have some structure, as the varieties which we encounter in our experience are structured. Thus, formalization of information may be started from some very general structure defined on the set S, or better on the family of all its subsets. If we start from the power set of S, we can consider both manifestations of information. We can consider membership of some of subsets of S in a distinguished family of subsets which gives us association with the selective information through the membership, and at the same time we can assume that the distinguished family of subsets consists of exactly these subsets which inherit from S its possible, original structure, which gives us an association with the structural manifestation of information.

Information itself can be understood in this framework as a collection of the subsets of this distinguished family which form filter (in the algebraic sense). This means that together with every subset in the filter, all subsets of the family including it also belong to the filter, and additionally the filter is closed with respect to intersection. The reason for using filters as a description of information is the fact that both a selection of one out of many and making one of the many has its consequences which also have features of information. White horse is a horse, so information consisting in selection of a white horse is also selecting a horse. On the other hand, the structural characteristics of a white horse include structural characteristics of a horse.

In a slightly more formal way, for the purpose of defining information we distinguish a family $\Im$ of subsets of S, such that $S \in \Im$, and which is closed with respect to arbitrary intersections. This family can be easily recognized as a Moore family of subsets of S which defines a (transitive) *closure operator* on S, i.e. set S with a function *f* called a closure operator assigning to every subset A its closure *f*(A), such that

$$\text{for all } A, B \subseteq S\text{: } A \subseteq f(A),\ \ A \subseteq B \Rightarrow f(A) \subseteq f(B), \text{ and } \ f(A) = f(f(A)).$$

The set S with a closure operator *f* form a *closure space* <S, *f*>. Every closure operator on a set S is uniquely defined by the Moore family of its *closed subsets* $f\text{-Cl} = \{A \subseteq S\colon A = f(A)\}$, and every Moore family $\Im$ of subsets of S, i.e. family of sets which includes S and is closed with respect to arbitrary intersections, is the family of closed sets for the unique closure operator defined by $f(A) = \cap\{B \in \Im\colon A \subseteq B\}$. It is easy to see that for every closure operator its family of closed sets forms a complete lattice L_f with respect to the set inclusion [Birkhoff, 1967]. Information is now defined as a filter (or dual ideal) in a set theoretical sense within $\Im$, or equivalently a filter in a lattice sense in L_f.

The semantic relationship between two information systems (i.e. between a system playing the role of a symbol and another system playing the role of denotation) in this formalism is given by a continuous function (in sense of generalized continuity for closure spaces more general than topological) from the latter to the former. It can be associated with the concept of a random variable for an extreme case of a Boolean algebra of all subsets of given set, and with an observable in another very special case of quantum logics. After all, magnitudes expressed in numerical form are symbolic representations of information inherent in physical systems.

This complete lattice of closed subsets L_f with respect to the set inclusion is of special interest, as it can serve as a tool to characterize and classify the structures (e.g. algebraic, geometric, topological, etc.) introduced in the set S, when the closure is defined by the Moore family of its substructures. We can call this lattice the *logic of an information system* described by the closure space <S, *f*>.

Even more important is the role of the lattice of closed subsets in the characterization of the level of integration of information in the system. There are two extreme possibilities. In one this lattice is completely irreducible, this means it is not isomorphic to the direct product of any pair or collection of lattices. This corresponds to completely integrated information. An example of such lattice can be found in the class of so called quantum logics, i.e. lattices of closed subspaces of a Hilbert space (here too we have a closure space) in the formalism of quantum mechanics [Jauch, 1968]. Irreducibility of quantum logic is equivalent to unlimited applicability of the Superposition Principle, which is the core characteristic of quantum mechanical systems.

The other extreme case is of a trivial closure space in which all subsets are closed, i.e. we do not have any structure on the set S. Then the lattice of closed subsets is distributive and is a Boolean algebra of all subsets. In physics this case is associated with a purely classical mechanical system. Boolean algebras are completely reducible to the direct product of trivial two-element structures. This corresponds to the case of completely disintegrated information.

There are possible intermediate cases when the lattice of closed subsets is reducible to a direct product of non-trivial irreducible lattices. In this case we can distinguish so called center, a subset of elements which form a distributive sublattice and has properties similar to the completely reducible case (disintegrated information,) but the factor lattices into whose direct product the lattice is reduced are completely irreducible. Each minimal element (atom) of the center corresponds to one factor. Thus, we have separation of the system into purely integrated portions of information which can be interpreted as identities of objects, and the part of information which is purely disintegrated and can be interpreted as that which describes the state of object or objects.

At this point it is important to notice the terminological discrepancy between the use of the term “state” here and in quantum theory, where there is no distinction between the state and identity of the quantum-mechanical object.

Closure spaces which have as their lattices of closed subsets purely quantum logics are very special examples of irreducibility. Quantum logics are defined with an additional structure of orthocomplementation (see Appendix) imposed over the lattice structure which allows for the definition of a generalized probability measure necessary to define a physical state, and from our point of view it is important that only then we can define entropy or other familiar measures of information.

While orthocomplementation is an independent structure from that of the lattice (in the sense that we can define two different orthocomplementations on the same lattice producing non-isomorphic ortholattices), this additional structure can be introduced without going beyond the language of closure spaces. However, the condition for closure spaces to admit orthocomplementation is quite restrictive. This means that the quantitative description of information is possible for a restricted class of information systems.

There is a legitimate question whether we need such a high level of generalization to include the cases when the familiar quantitative description is impossible. The answer is positive, as there are many important information systems described in terms of closure spaces which do not admit it, such as for instance geometric or topological information.

Appendix

In the following, the basic concepts of quantum logics are reviewed for the convenience of the reader, as they provide a very important special instance of the more general structures of the logic of information (as described above) in which it is possible to introduce probability measure, and therefore familiar forms of information quantification. More details can be found in a variety of books on the subject [Jauch, 1968].

The quantum logic formalism of quantum mechanics (in its most conservative form) can be understood as reformulation of the Hilbert space ("standard") formalism in the more abstract terms of complete orthocomplemented lattices and probability measures defined on them, generalizing the "classical" probability theory on Boolean algebras. There are some further generalizations of the concept of quantum logic which are of little interest for us, as they require separation from the conceptual framework of closure spaces. Thus, the conceptual basis of quantum logic presented here consists of the partial order relations with the increasing level of completeness (lattices, complete lattices) and their dual automorphisms.

The fundamental structure of a purely quantum logic is defined as an orthocomplemented, orthomodular, complete atomic and atomistic lattice with the atomic covering property and exchange property.

Thus, it is a complete lattice $\langle L, \wedge, \vee, 0, 1\rangle$ with the meet operation "$\wedge$", and join operation "$\vee$", the least element "0" and greatest element "1." The lattice structure is associated with the partial order defined by:

$$a \leq b \text{ iff } a\wedge b = a \text{ iff } a\vee b = b.$$

In a lattice L with the least element 0 we can distinguish a subset of elements called atoms

$$At(L) = \{p\in L: \forall x\in L: 0 \leq x \leq p \Rightarrow x = 0 \text{ or } x = p\},$$

whose elements are all minimal non-0 elements.

The lattice defining quantum logic is atomic, i.e. every element of the lattice is greater than or equal to at least one atom. It is atomistic, i.e. every element is a join of atoms smaller than it.

Also, it has the atomic covering property which means that $\forall a,b\in L \forall p\in At(L)$: $a \leq b \leq a\vee p \Rightarrow a = b$ or $a = a\vee p$.

Finally, it has the exchange property which means that $\forall a\in L \forall p,q\in At(L)$: $a\wedge p = 0$ and $p \leq a\vee q \Rightarrow q \leq a\vee p$, or equivalently $a\vee p = a\vee q$.

In an atomistic lattice the last two properties are equivalent, and such a lattice is called simply an AC lattice.

Now, we can introduce a concept which goes beyond the formalism of lattices.

An orthocomplementation on L, is an involutive anti-automorphism, i.e. a bijective mapping of L on itself ($a \rightarrow a^*$) such that: (1) $a^{**} = a$, (2) $a\leq b \Rightarrow b^* \leq a^*$, and $a\wedge a^* = 0$ and $a\vee a^* = 1$. Frequently, the fact that $a\leq b^*$ is written $a\perp b$ and is read "a is orthogonal to b." A lattice with an orthocomplementation is called an ortholattice. The separate term "ortholattice"is justified by the fact that the same lattice can admit two non-isomorphic orthocomplementations.

In an ortholattice the properties of being atomic and atomistic are equivalent.

Boolean algebra is an example of an ortholattice, with the complementation playing the role of orthocomplementation ($a\rightarrow a^*$ can be simply defined by $a\wedge a^* = 0$ and $a\vee a^* = 1$, as for every element a there is exactly one a^* which satisfies this condition, while in general there may be many such elements).

Atomic Boolean algebras play a very special, and in some sense trivial role of the purely “classical logic” characterized by the distributive property. Lattice L is distributive if $\forall a,b,c \in L$: $a \wedge (b \vee c) = (a \wedge b) \vee (a \wedge c)$.

Distributive equality is not satisfied in quantum logics of quantum mechanics, and actually, the violation of this rule is critical for the distinction between the classical and quantum mechanics. The “global” classical character of the logic for classical mechanics can be localized to a pair of the elements in any ortholattice. We call two elements compatible aCb if $a = (a \wedge b) \vee (a \wedge b^*)$. Of course, in a Boolean algebra every two elements are compatible, while in the purely quantum case we will have that the only elements compatible with all other are 0 or 1.

In every ortholattice L, $\forall a,b \in L$: $a \leq b \Rightarrow aCb$, but in general not necessarily bCa. Quantum logics are required to have the relation of compatibility symmetric which is equivalent to the requirement of orthomodularity.

An ortholattice L is orthomodular if $a \leq b$, then $b = a \vee (b \wedge a^*)$.

This property is equivalent to the condition that for any pair of elements $c,d \in L$ such that $c \leq d$, the interval [c,d] of L, i.e. the set of elements $[c,d] = \{x \in L: c \leq x \leq d\}$ which always forms a sublattice, is a sub-ortholattice, with respect to the orthocomplementation defined by $a^{\#} = (c \vee a^*) \wedge d$.

While the relation of compatibility describes the classical aspect of the structure, the atomic bisection property or in other words irreducibility property refers to the quantum character. The condition of irreducibility or coherence is defined in terms of atoms. If p and q are different atoms of L, then there exists a different third atom r, such that $r \leq p \vee q$, or equivalently that $p \vee q = p \vee r = r \vee q$. It is called the Superposition Principle, as it is a counterpart of this principle in the conventional formalism.

It is easy to see that this condition is never satisfied in Boolean algebras, but is an axiom for quantum logics (exchange property.) Moreover, if it is satisfied by an omolattice L (short for orthomodular lattice,) then the only elements compatible with all other elements of L are 0 and 1. Thus, it is a characteristic of a purely quantum or purely coherent system.

The name irreducibility condition comes from the fact that it is equivalent to the condition that the quantum logic is not isomorphic to a direct product of other quantum logics. On the other hand every atomic complete Boolean algebra is isomorphic to the product of two element Boolean algebras, each of them trivially satisfying the condition of irreducibility. The intermediate case (quantum, but not purely quantum logic) will be the case when given quantum logic is isomorphic to a product of its nontrivial, coherent, irreducible components. There is a bijective correspondence between the coherent components of L and the atoms of the center of L, i.e. of the set of the non-0 elements of L which are compatible with all elements of L.

The following representation theorem is irrelevant for the objectives of the article, but it is included here to explain the relationship of the quantum logic formalism to the standard formulation of quantum mechanics.

Every purely (i.e. irreducible) quantum logic, i.e. an orthocomplemented, orthomodular, complete atomic AC lattice (the redundant conditions have been eliminated) can be represented by a lattice of closed subspaces of a general Hilbert space. There is some additional condition necessary to have representation in a Hilbert space over a field such as of complex numbers in the standard formalism of quantum mechanics, but it is of no interest in this context.

It has to be emphasized that in the usual case of quantum mechanical physical systems which admit superselection rules their quantum logics belong to the partially reducible intermediate type.

On a quantum logic (not necessarily irreducible,) we can build full physical formalism of quantum mechanics by defining states of the physical system by generalized probability measures. The axioms are basically the same as in classical probability on Boolean algebras, so it is the underlying ortholattice structure which makes quantum probability different.

The state on the quantum logic L is a probabilistic measure μ: L$\rightarrow\Re$, such that

(1) $\mu(0_L) = 0$, $\mu(1_L) = 1$,

(2) For every $a\in L$: $\mu(a)\geq 0$,

(3) For every countable family of mutually orthogonal elements of L,

$$\vee \{a_i\in L, i\in N: \forall i,j\in N: i\neq j \Rightarrow a_i\perp a_j\} = a \Rightarrow \mu(a) = \sum \{\mu(a_i), i\in N\}.$$

To complete the physical formalism, we can define observables (physical magnitudes) as ortho-homomorphisms from the Boolean algebra of Borel subsets of the set of real numbers to the quantum logic. It is easy to see that observables are equivalent to random variables, but defined in the more general context of quantum logics. In classical probability, the random variables are usually defined as functions from the set of outcomes to real numbers, but they can be defined in an equivalent way as above.

When a purely quantum logic is represented by an ortholattice of closed subspaces of a Hilbert space, or as an ortholattice of projections in a Hilbert space, the observables defined for the quantum logic become selfadjoint linear operators defined by their projection valued spectral measures.

What is a natural description of quantum coherence in terms of irreducibility cannot be reintroduced in terms of a Hilbert space, as each coherent component (or rather factor) of a reducible quantum logic requires a separate Hilbert space representation. This explains why superselection rules corresponding to the reducibility conditions for a quantum logic do not have easy interpretation in the conventional formalism.

As we could see, the concept of an orthomodular lattice is a generalization of the concept of a Boolean algebra, so quantum theory can be considered a generalization of probability theory. There is a natural question in what degree the structure of orthocomplementation imposed on the lattice of quantum logic is restricting the choice of closure operators for which this lattice is the lattice of closed subsets. The answer is that even if we eliminate the condition of orthomodularity the restriction is quite strong. It turns out that such closure operator can be defined by an appropriate symmetric binary relation [Ore, 1943].

Many lattices interesting for the purpose of the study of information, for instances lattices generated by some geometric or topological structures, do not satisfy this condition. Thus, the formalism of general closure spaces which seems to be a good for the study of the structural manifestation of information is too general to be used in the quantitative analysis of selective manifestation of information, as long as we have to use some form of probability measures.

Conclusion

The formalism presented above is only a first step towards authentic theory of information. Its strength is in giving the framework for considering a very wide range of contexts in which the pre-systematic concept of information has appeared (to the best knowledge of the author virtually all contexts). Its another strength is in being based on a philosophical foundations which are very general, but also highly nontrivial in the sense that in the form of the reflection on the opposition of one and many they have been studied in connection with all fundamental problems of philosophy. On the other hand, the concept of information formulated within this conceptual framework is very promising in giving answers to philosophical problems belonging to most difficult in the intellectual traditions of many cultures.

Since the presentation of the formalism is very concise, many of its aspects require more detailed exposition which is included in forthcoming papers of the author. In better understanding of the formalism two very special instances are very useful, that of completely disintegrated information described within Boolean algebras of subsets, and that of completely integrated information described in quantum logics. However, specifics of these two instances (for instance existence of orthocomplementation in the lattice of closed subsets giving an easy association with traditional logic) can be misleading. The need for consideration of geometric or topological types of information requires much higher level of generality.

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Major Fields of Scientific Research Related to Information: Philosophical and formal aspects of information; Theoretical models of consciousness; Information integration;

LOGICAL STRUCTURE OF CHROMOSOMES

Karl Javorszky

Abstract: *We established by function analytical methods that maximally structured assemblies number differently many logical constellations in dependence of the human’s interpretation of the symbols structuring the objects. If the human spectator reads into a multitude of symbols on objects the interpretation that the objects are to be read sequentially, he arrives at a different result relative to the result he arrives at if he supposes that the objects are not sequential but commutative. The intrinsic meaning of the dichotomy commutative – sequential is of such basic importance in Nature that in fact the human perception uses this linkage while it structures and interprets the impulses rendered by the sensory organs. The new approach discounts and actively counterbalances the neurological preferences of the brain and creates a logical-numerical model which accommodates the less pleasing aspects of logical objects, too. We created a logical tool which demonstrates the inner interdependence between quality and place. We discuss a basic logical problem, namely, the space-matter interdependence. The same logical operation is at work behind different views of the same problem: “where is what?” The matter-space interdependence offers conceptual solutions to questions in a wide range of applied sciences. For genetics, it may be helpful by showing that the natural unit of translocation is a triplet of arguments. We expand the discussion of the logical sentence a+b=c, the usual foreground, by the expression u=b-a, k=u-b, t=u+k=2b-3a, q=a-2b, s=17-c, w=2a-3b, the background, for the first 136 additions (a[1..16], b[1..16]). We use the arguments kutqsw as freely as abc to sort on. We compare the changes in relative positions of each instance of a+b=c within the collection of additions. The place changes resulting from a resort are a realisation of the change in the relative importance of the arguments, which is denoted by the position of the argument within the sequence of arguments. Using the logical parameters abckutqsw as a sequence and permutating the arguments, one observes that not only the position, but also the number of .t. values changes in the implicated table of identities of sorting orders. The findings allow a logical approach to the terms “structure”, “time”, “translation table linear sequence – spatial structure”. The positions of logical markers are indeed dependent on the sequence of logical arguments.*

Keywords *Genetic information, Logic, Information Theory, Theoretical Physics, Theoretical Chemistry*

Introduction

This paper is a proposal to look more deeply into a discovery in the realm of basic science. We state that the basic logical translation mechanism governing genetic information transfer has been found. Results from research in basic science are inputs in applied sciences. Exactly this situation is to be observed here.

Basic research addresses questions that appear at first not to be too relevant for applications. The translation into patents, gadgets and tools that utilize the new approaches may appear quite long-wound and complicated. Yet, bio-informatics being one of the absolutely hottest topics, the work of adaptation into actual physical devices of production – of, say, enzymes – or of measurements – of, say, probability of genetic modifications being successful -, or in other fields of practical application will yield quite significant advantages.

The very idea that the process biology, medicine, genetics, the law and theology call "life", specifically with its multi-faceted connotations as "human life", is subject to a logical, combinatorial and rational explanation may cause disillusion in some. The idea that a rational explanation for the functioning of reproduction exists implicates the absence of any divine involvement. The day a rational explanation for the genetic interplay between organism and DNA will have been accepted as valid, an era will have come to an end. There are some inner resistances to be overcome until the realization that the "secret" behind the two lines of triplets, twisting in the chromosomes, can be decoded, because it obeys simple combinatorial rules.

Previous Research

The literature offers little hope, there are even hints that the combinatorial mechanism *cannot be found* by methods of classical logic and mathematics. This goes back to the efforts of many, of whom we mention pars pro toto the Santa Fe Institute, where Adleman led a project which in effect proved futile. The books on the subject have been closed, so frustrating was the experience. Scientists educated in the tradition of classical mathematics *can not* solve the combinatorial problems behind genetics, as they themselves were forced to admit.

What was never in question is the certitude *that* a rational solution exists. Practical observation of the interplay (*this* person → *that* DNA, *this* DNA → *that* person, *each one specific* person ↔ *each one specific* DNA), put to use by criminology, medicine and paternity lawsuits e.g., is proof enough that a *bijective* or, at the least, *quasi-bijective* relation exists between the DNA and its organism.

Theoretical work related to descriptions and the objects described is best exemplified by conclusions arising from the Tractatus by Wittgenstein and subsequent clarifications by Frege and Carnap in the field of symbolic logic. The DNA is a description of an organism. It is a sentence in a logical language. One word in this language is a triplet. The triplets are *sequenced.* The meaning of each sentence is – somehow – translated into a different way of putting it, where an organism is described by *many* sentences that each are *concurrent.*

While – in an abstract, simplified way of putting it – the DNA is *one, long* sentence of which the words are *sequenced,* the resulting organism is described by *many, short* sentences that are *contemporary.* (It is *concurrently* true of Mr. X that his blood pressure is 120/80, his eyes are blue and his feet are hairy. None of these facts are predecessors or successors to the other facts, like the triplets of his DNA are ordered as predecessors and successors.)

The theoretical task is then to find the link between two descriptions about one and the same state of the world. Mr X is as well described by one, long sentence in the sequenced language as by many, short sentences in the commutative language. The link obviously functions; it is only us, human researchers, who are too misguided, too much full of misconceptions to find the simple and self-explaining logic regulating the translation *sequenced* ↔ *commutative.*

About Explanations

In the Tractatus, Wittgenstein shows that the methodology of scientific thinking results in following requirements for a rational explanation of phenomena of Nature:

- The explanation is best if it is interpersonal, that is, uses words that have a meaning commonly agreed on;
- The words used in a scientific discourse should ideally have a very precise meaning, the relation of the meaning of each word to every other word being clarified at the beginning of the discourse;

- The explanation cannot discover anything new, because the fact that an interdependence among words is such as the explanation explicates – lays open for all to understand - is independent of the person or the time of the explanation, that is, Nature cannot contain any mysteries if explained rationally;
- The explanation is necessarily a tautology and is among the combinatorial possibilities that are included among the words of the language.

These are strong hints that a rational – or Pythagorean - explanation will

- Use a language that is public, that is not dependent on cultural connotations;
- The words of the language shall have each as clear a denotation as the numbers;
- The sentences constructed by the words of the public language shall have a clear result of evaluation {.t.|.f.};

The actual interdependence exists independently of a human interpretation in and among the words of the public language.

Summarising previous research

Efforts have been made with goals of finding the logical interconnection between the DNS and the living organism; these efforts have been given up. The present approach recommences the previous efforts. Both previous efforts and the present approach are rooted in the work of Wittgenstein, who has shown that:

a rational explanation *exists* for phenomena of Nature;

a rational explanation is necessarily a *tautology;*

being a tautology, the explanation will contain *no surprises;*

the more *formal* the explanation, the better it is *understandable.*

Footnote to Wittgenstein: if there is a surprise arising from – caused by – an explanation, the surprise can only relate to the human nature. As Nature itself holds neither puzzles nor mysteries, it is only our own way of looking at Nature that is puzzling and mysterious. How could we have maintained such an evidently erroneous picture of the world, relative to which Nature appears complicated?

A scientific discovery can only surprise us with respect to our ability to have hidden the obvious before ourselves by the methods we used to maintain an illusion. Had we looked at the world as it is, and not as we wish it to be, we had been able much sooner to see that what we have hidden from ourselves for so long. There is always an anticlimax, disillusionment once one understands an explanation. As the explanation is necessarily a tautology, the puzzle was necessarily a self-made one. Had we not insisted that the Sun rotates around the Earth – for reasons that have nothing to do with astrophysics -, the actual facts had been accessible much easier and sooner.

General idea

Clarifying the logical structure of the DNA leads of course to a tautology, and the only surprise we can experience is not about the DNA, but about ourselves: by which mechanism, what pattern of perceptional artefacts had we been able to hide the obvious facts from ourselves for so long. So, the story about of what is new on the explanation relates to successive steps of clarification on what we have to unlearn, or see otherwise, before we can understand that the DNA cannot work otherwise but in a tautological fashion. First we have to *deconstruct* the convictions that are analogous to the sensual experiences that the Sun is raising and setting, not the Earth circling. We have no sensual feeling that the Earth circles; and the sensual feeling that tells us that the Sun moves is overwhelmingly self-evident.

The situation is similar with respect to understanding genetics. We have an obvious sensual certitude that rational thinking is best achieved by considering *similarities* as the main, important aspect of logical objects and that *dissimilarities* are of no relevance in rational thinking. The general idea is that it pays to take *dissimilarities* – which we are used to utilise as the background of perception – equally valid to use as the *similarities* which presently monopolise rational thinking. The answer may lie in that small detail which we have by tradition learnt to neglect.

The idea of a maximally structured set

Both the DNA and the organism are *maximally structured sets.* Both the DNA and the cell(s) it describes/creates are free of any random or stochastic components. The effects described by biology as “mutation” and “variation” are at first set aside. (The surjective slack in the map sequenced → commutative we call “variation”, the injective slack commutative → sequenced we call “mutation”.)

A set so much full of symbols that any additional symbol is redundant is called a maximally structured set, irrespective of the human spectator’s decision to view the objects carrying symbols as commutative or sequential.

Differently many states of maximally structured sets

One regards a set of n objects carrying symbols. It is one’s own decision whether one looks a sequence into the objects or not. In case one regards the objects carrying symbols as a *sequence*, the upper limit for the number of distinct states this assembly can be in is well known (namely $n!$).

In case one regards the objects carrying symbols as *commutative*, the upper limit for the number of distinct states this assembly can be in is not well known. The term used for this concept is called *multi dimensional partitions*, and the concept is not defined.

Although in a formal, mathematical sense not defined, the concept still exists and merits investigation. In psychology, a concept of which one does not know {much | enough | everything | anything at all} is an interesting concept worth while to look more deeply into. If a concept has got a sufficiently detailed and exact definition, it ceases to be an idea of interest to psychology, save maybe some fields of applied psychology like ergonomics. We are very much attracted by things we do not know everything about.

Commutative assemblies of objects that have more symbols than needed are such an object of interest. These are in a fashion antipodes to the Kantian object as such, insofar as that one is one single object and is devoid of any properties, while this concept consists always of a multitude and may well have quite many and varied properties.

As a psychologist, one may not be able to give a definition of *what* something is, but it is quite legitimate to deal with it and e.g. count *how many differing and distinguishable appearances* it might have.

Sequenced and Commutative Number Differently Many

The number of distinct *sequential* states of a maximally structured set is known: $f_1(n)=n!$. Counting the states of a *commutative* set yields $f_2(n)=n?$, where $n?$ denotes the number of partitions of n raised to the power of the logarithm of the number of partitions of n.

$$f_2(n)=part(n)^{ln(part(n))} = n?$$

This is not the place to give a detailed reasoning for the result *n?*. It may be sufficient to mention that test theory states that one cannot validate more tests on *n* subjects than a number $f_v(n)$, and that one cannot classify subjects into more test results than $f_t(n)$, where *n* is the number of items of a test. This allows the implication that assignment of symbols to objects cannot be more than of objects to symbols, therefore the result must be a quadratic expression. As all assignments of symbols to objects and of objects to symbols number equally many, the above result follows.

The relation is best shown by means of Fig. 1, where *n?* is normed on *n!*.

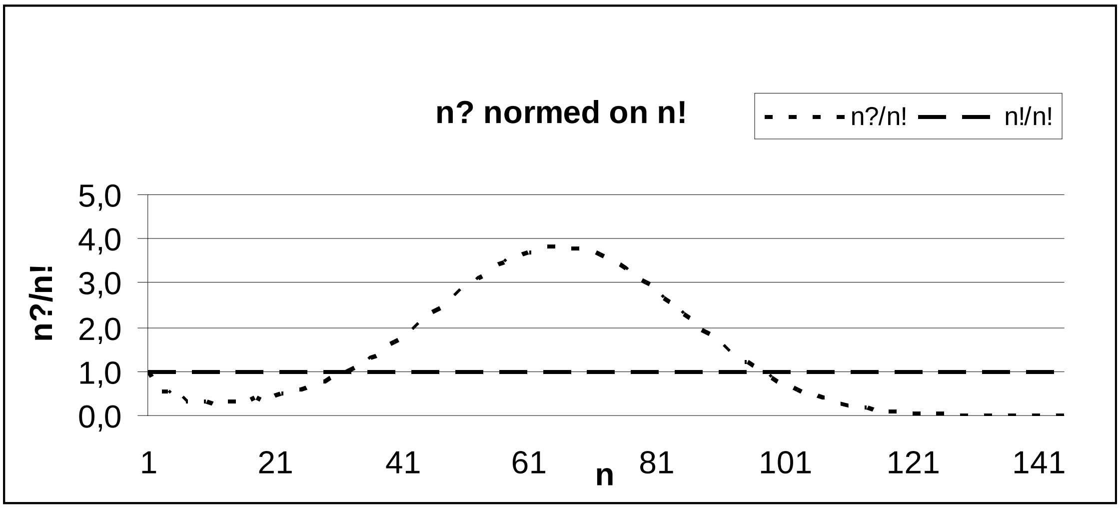


Figure 1: Number of sequential vs. commutative states

The Figure shows an interdependence which explains how the copying to-and-fro between a *sequenced* and a *commutative* collection can function. In dependence of a – maximally structured - collection consisting of parts that number between 33 and 96, there are more logical *properties* to it than logical *places* along a continuum exist for that many properties. This means that the question is *whether* parts of a whole are more *parts* of a whole or parts of a *whole,* that is, one has to address the deeper mysteries of additions. The task is to find the real logical, inner, difference between a logical complex expressed as a three-fold of 45 units and and/or a two-fold of 67, above a numerical inconsistency of unit extent (the unit being anyway once *three* and once *two* sub-units, as genetics shows).

Reviewers of this idea have stated that the mathematical concept of a commutative set having a maximal number of non-redundant symbols appears still not sufficiently clearly defined, and that the whole mathematical problem appears unclear. This is of course true. We have arrived at numeric values of *n?* not by mathematical, but by *accounting* methods. The aim of this present paper is to draw attention to the fact *that* a mathematical problem exists, and that the existence of this *unclear, murky* problem allows inroads to understanding *messy, wet, slimy, living* logical states that we encounter while dealing with the information transfer between a *sequence* and a *commutative collection*.

We interpret the functions as showing that Nature employs an accounting trick. The *number* of logical entities varies with their qualitative and spatial attributes. If one reads an assembly as a *sequence* of 12 units compared to a background of 67 *commutative* units, one has a translation coefficient of around 3.8. Information can be represented in the sequenced – classical, Boolean, von Neumann – fashion, and it can be represented as a structure, a collection of symbols. Either the spatial coordinates have a dependent role, or the commutative properties are dependent on the spatial praemisses.

Anthropomorphic Attitudes Towards Logical Objects

The numerical inconsistencies of the interdependence between sequenced and commutative readings of one and the same collection of objects carrying symbols mean that there is an inner contradiction in our whole attitudes towards counting and deducting. We polarise the inner ideas of “sequenced” and “commutative” and use the difference between the moment and the flow of time in the functioning of the brain. Our system of perception and of thinking distinguishes quite efficiently between temporally *transversal* and temporally *longitudinal* experiences. That what is in the moment is experienced differently to that what changes.

We experience the temporal order as strictly sequential. In the cross-section of time, there are many different impressions which we categorize into feelings, ideas, concepts and so forth. These are much more varied than the uniformly equalizing aspect of time flowing.

There is an order connecting the momentary, actual representations of reality with their predecessors and successors: otherwise we would become incoherent, sick or dead. The predictability of a person is one of his most determining properties, and culture and instincts together regulate quite finely the degree of consequentiality by which the next element in the behavior of the person can be predicted from previous or current states of that person. In normal life, we use the translation coefficients between present state and previous state as we understand something somebody says by relating it to his previous words, and we can predict a behavior of a person based on his momentary state (of mind, of body, etc.).

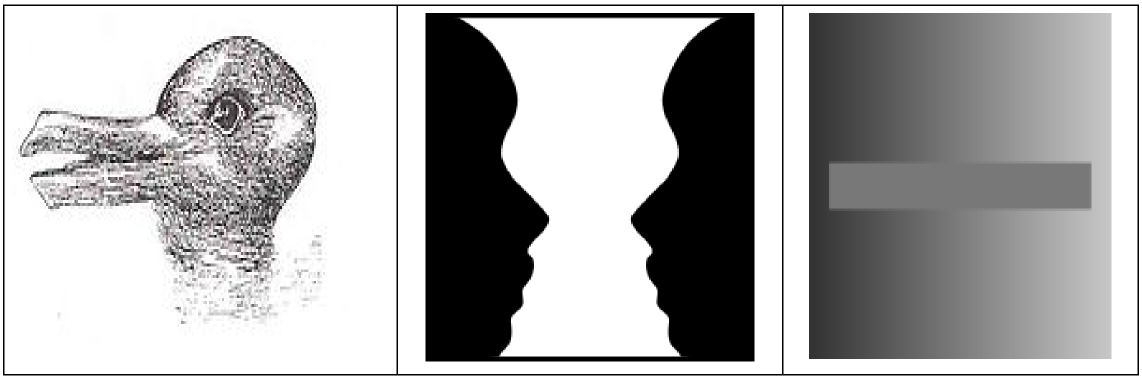
What we use every day we get used to and treat it as a self-evident truth. So this can be a moment of deconstruction as we approach the idea of a set being concurrently commutative and sequenced.

The human nervous system makes it not easy to switch between foreground and background.

Difficulties Encountered While Switching Between Alternatives

The attitude to polarize the viewpoints of a set is deeply engrained in the human nervous system. The task is to make understand that the *human mind* switches between a picture of a collection as a sequenced one and a picture of the same collection as a non-sequenced, commutative one. We humans have got used to it, we have learnt it so and we experience it so. People normally *believe* that something is *either* sequenced *or* commutative and usually are *unable to* – or at least need explicit illustrations – to discover the other way of looking at structured sets.

The need to change views when dealing with foreground-background problems and/or the inner decision to distance oneself from the neurological artifacts that make us perceive optical illusions can easily be demonstrated by the following illustrations:



The well-known *duck or hare* and *vase or profiles* optical illusions teach one to switch between *foreground and background* while the grey bar illusion teaches us to relate the foreground to the background.

Humans deal with problems by relating it to other, similar cases, before a background of different cases. That, what does not belong to the problem in question yields the background before which that, what is of interest can be perceived. The idea is that the *un-sequenced, commutative* is the background for the sequenced and the *sequenced* is the background for the commutative. We then always compare how well the impressions are sequenced while they are so as they are, and at the same time we evaluate how well-composed, well-fragmented are the properties of the present, commutative collection of impressions, relative to how we expect them to be based on the sequence so far. This is a technique composers, dancers, poets know well. The interplay between the sequential position and the quality of a logical object can well be demonstrated on a collection of logical statements that are in themselves commutative, yet always in a sequence. This is what we do by means of the Addition Table.

A Fresh Look at Additions

To perceive the *cuts* on an interval to be as important as the *continuities* between the cuts means to understand that there is more to additions than at first meets the eye. The cuts separate the units. At school we have learnt to abstract 3 apples in 3 units and learnt that the abstract idea of units is as easily demonstrated by lengths of lines. In the one-dimensional way of putting it, we have learnt that an interval of length *a* is to be seen as a sequence of *a* units stretching from Origo to *a* with cuts separating the units.

At school we have been given a very general picture of additions. One has been actively discouraged from distinguishing e.g. 3+4 from 2+5, because the general idea of additions is fusing the two extents; and the result is the same, whether we have fused parts where the “between” cut was at 3 or such where it was at 2. We have learnt to disregard the *place* of the cut. Now we re-introduce the *dissimilarity* property of the logical objects into rational thinking and handle the two logical objects *a* and *b* in more fashions than joining them. Counting – as understood in the classical sense – relies on the *similarity* of the logical objects into which we abstract the objects we learn to count (apples, lamb, ducks, houses, etc.). We have learnt that it is the aspect of *similarity* which is of relevance and the *dissimilarity* is irrelevant.

Instinctive Gratification

We *know* that similarity is the important attribute of the objects we perceive when simplifying and abstracting many objects into categories of objects. The thinking process is built on categories of objects that are *similar.* Prior to thinking, we learn by means of the memory, and one of the main ordering principles of the memory is doubtlessly the *similarity* of neural impressions. Without similarity of the present impression with an experience remembered learning cannot take place. The animal will return to the same place where it has found food, and recognizes the sameness of the place by the maximal similarity of its impressions. The memory and the perception yield results that match, that is, are as similar as possible.

The human animal gains survival and reproduction advantages if its nervous system optimizes on some specific patterns of recognition. We cannot but feel an intense gratification of remembering correctly and thinking in an orderly fashion by using the *similarity* property of the contents of the central nervous system (be they momentary or remembered impressions). The gratification arising from using the similarity property of logical objects is an inherited artifact of intelligence. It is easy to see that those animals that do not recognize a present experience to be similar to a previous experience are less able to compete in the process of survival and reproduction. We are attracted to the similarity property of logical objects by its advantages as a supernormal stimulus (like moths to light).

Counteracting Artifacts of Human Neurology

The system of counting is based on the basic idea that any natural number *n* is made up of *n* pieces of logical objects of unit property – which we call 1 -, that are absolutely similar in all respects one to the other. This idea has been shown to be gratifying for the neurology and stabilizing for the psyche, but may be an oversimplification for dealing with Nature.

In order to undo the neurological artifacts, one should effect some changes to the system of additions. The following proposals apply:

Attitude caused by artifact of natural selection	Proposed correction for holistic approach
Distinguish the foreground to the background;	Use both background and foreground as two – equally legitimate – sides of 1 coin
Focus on one object at a time;	Use a collection of additions as unit
Establish similarity properties of objects;	Use dissimilarity properties concurrently
Count similar objects;	Use several aspects of (dis-) similarity
Distinguish between spatial position of an object and its type;	Use that *how* something is determines *where* something belongs
Disregard irrelevant aspects;	Classify aspects into relevant 1, relevant 2 and irrelevant
Relate to a stable background;	Assume continual switches and rearrangements: which is the background
Distinguish between things you feel tactile and otherwise;	The *object* and *properties* of the object are logically of the same nature
Build a system according to your preferences;	Allow the system to appear viscerally wrong, if only logically stringent
Experience time as immaterial.	Show temporal processes to be closed loops

There are of course many more possibilities to look for a logical system that tries to be less anthropocentric, but these few proposals should be sufficient to seduce the reader into looking into the matter.

Presenting the Tool: Addition Table 1.0

The Table is quite easy to build, as it consists of *a*+*b*=*c* with 1..*a*..16, 1..*b*..16. Columns 1 to 3 are as follows.

Table 1: The first 3 columns of Addition Table 1.0

A	B	C	A	B	C
In sorting order AB			In sorting order BA		
1	1	2	1	1	2
1	2	3	1	2	3
1	3	4	2	2	4
1	4	5	1	3	4
…	…	…	…	…	…
…	…	…	…	…	…
…	…	…	…	…	…
15	15	30	14	16	30
15	16	31	15	16	31
16	16	32	16	16	32

There are 136 rows in the Table. ΣA=816, ΣB=1496.

Aspects of Additions

We put to use a detail which we were instructed at the age of 6 not to consider important, namely *u*=*b*-*a.* This distinguishes e.g. 2+4=6 from 1+5=6.

We furthermore create following aspects:

k=u-a=b-2a

t=k+u=2b-3a

q=a-2b

w=2a-3b

s=17-{a+b|c}

We have now 9 *aspects* of an addition, namely l,m,r,k,u,t,q,s,w.

Ordering on Pairs of Aspects

We create *sequential sorts* on the 136 additions by using aspects α, β as sorting criteria, where α, β are any two of the aspects. A sequential order within the collection of 136 additions is arrived at by using α as the 1st and β as the second sorting criterion. The resulting sort we call $SQ_{\alpha\beta}$. There are 72 $SQ_{\alpha\beta}$.

Finding Identical and Distinct Sequential Orders

We create Comparison Vector V[1..5184] whereinto we harvest the results {.t.|.f.} of comparison $SQ_{\alpha\beta}$ with every other SQ. There appear *non trivial* results showing that *not only* the position of the .t. will depend on the sequence of arguments *a,b,c,k,u,t,q,s,w* that have generated the Table, but also *the number* of .t. values will depend under some conditions on the sequence of the aspects. In dependence of the *sequence* of the arguments while creating the table, ties can appear. If the elements in ties show that a previous sort on different arguments has previously taken place, the comparison will yield .t., and how often this will be the case is dependent on the sequence of the arguments.

Explication of Some Terms

The term *aspect* shall refer to each one of the expressions l,m,r,k,u,t,q,s,w defined above. We refer to any of the aspects with signs α, β, γ, δ, (α≠β, γ≠δ). The term *relevance* shall refer to any α,β being a part of the name $SQ_{\alpha\beta}$. The 7 aspects that are neither α, nor β are not relevant for $SQ_{\alpha\beta}$. The term *importance* shall refer to the sequential number 1..*i*..9 denoting the sequential number of an aspect during the creation of the Table. The lower *i*, the higher its importance. The term *structure* shall refer to the collection of .t. values in Vector V.

Main Statement

The structure of a set depends on the relevance and importance of the aspects of the description of the set.

In a logical discussion about parts and the whole, the impressions of the humans will depend on the rhetorical methods used: which aspect is offered first – as the most important -, and which aspects are left as less important. This depends on the *sequencing* of the arguments.

In dependence of the *sequence* of the arguments, the collection of possible resulting structures will include different structures. Each of the structures itself is *contemporary* and *commutative.* The result of a different sequencing is a different commutative structure.

Dynamic Changes of Relevance and Importance of Aspects

We may assume that Nature does not obey our preferences of similarities but treats each aspect equally. Therefore, a constant process of re-arrangements is supposed to take place. If order αβ – as expressed by $SQ_{\alpha\beta}$ – changes into order γδ – as expressed by $SQ_{\gamma\delta}$-, we say that γδ are now *more important* and/or *more relevant* than αβ. This is what we *think* and *say.* What we *see* as the result of a change in the importance and/or relevance of aspects is a series of *place changes*, if $V[SQ_{\alpha\beta},SQ_{\gamma\delta}]$=.f., if the previous and the present sequences are at all different.

Place Changes as Consequences of Changes in Importance and Relevance of Aspects

We create a Secondary Table, a Table of Movements. A reordering of the importance and/or relevance of the aspects has as a consequence that place changes take place in the case that $SQ_{\alpha\beta} \neq SQ_{\gamma\delta}$. The resulting place changes are recorded in Sub-Table T in the form T_αβ_γδ. There can be several T_αβ_γδ, in which case one numbers them consecutively. Let me include as an illustration $T\_LM\_ML_3$, which is the first meaningful “thread” (“loop”, “chain”) of place changes resulting from a re-ordering of order LM into order ML. The chain consists of 18 steps and runs as follows: {3, 4, 7, 22, 23, 30, 107, 114, 115, 130, 133, 134, 120, 116, 66, 71, 21, 17}. The chains are of fundamental importance in logic and in descriptions of Nature. That pair of (*a,b)* which was previously on place 3, comes now to place 4. That pair of *(a,b)* which was previously on place 4, comes now to place 7. … That pair of *(a,b)* which was previously on place 17, comes now to place 3.

Chains with Unit Properties

The chains are a logical consequence of a change in perspectives (if the relevance and/or the importance of aspects changes, we speak of a change in perspectives). As we cannot and will not decide, which perspective is a "right" one, we assume that each and every change can and will take place. We find that there are but 18 *clans* (families, tribes, clones) of *actually different* sequential orders $SQ_{\alpha\beta}$, thence up to 18*17 possible T_αβ_γδ bunches of chains. (Within a rearrangement T_αβ_γδ there can be several chains, which we refer to collectively as a bunch of chains.)

Among these, the most important are those with *unit properties.* These appear as bunches of 45+1 chains, 45 chains of length 3 and 1 of length of 1. The solitary chain is always "*6+11=17*". The other 45 have as one of striking properties that $\Sigma L=18$. There appear three separate families of bunches of chains (see following paragraph), which centre around 67, 70 and 76 respectively.

Two Euclid Spaces Connected By One Double Plane

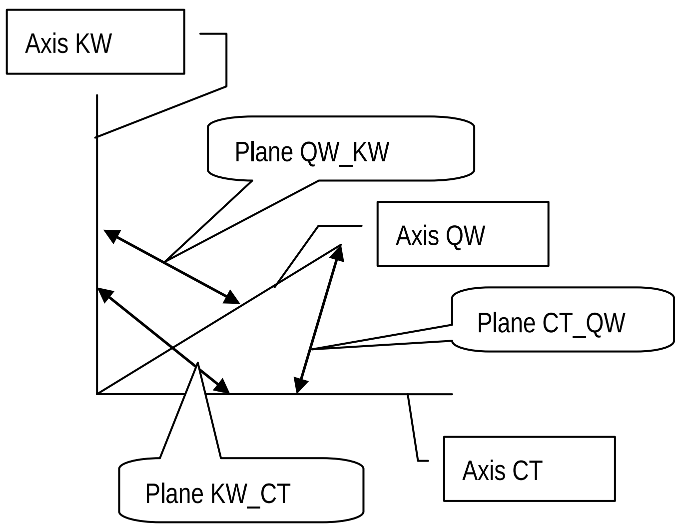
The changes-in-order in which we find the unit changes – exactly: the perspective changes which result in unit changes – are as follows:

CT_QW, KW_QW, KW_CT and CW_QT, KC_CW, KC_QT and AC_UW, AW_UC, in the case the Table has been created in the "classical" sequence *abckutqsw*. Other sequencings bring forth differing *names* for the unit changes, while their *properties* remain.

One will notice that two Euclid spaces can easily be constructed with axes CT, QW, KW and CW, KC, QT, where each of the axes has a unit length of 136 with equal steps of 1, as the underlying concept is that of a sequential number 1..136.

The Figure shall give an impression of the Euclidean nature of the 3 common axes.

Figure 2 Illustration of the Euclidean Nature of Changes of Unit Nature



The Axis CT is an actual sequence 1..136, giving the sequential position of each expression *a+b=c* in the sorting order CT. The Axis QW is an actual sequence 1..136, giving the sequential position of each expression *a+b=c* in the sorting order QW. The plane CT_QW is given by the *place changes* arising from a re-sort from CT into QW.

The planes AC_UW and AW_UC are both connected to both Euclid spaces. A logical statement of the form "perspective change of: from αβ into γδ, for *a,b* has the consequences of unit changes ...." can be interpreted to be relevant and/or important with respect to the *spatial* properties of *a,b*.

Interpretation

The chains of unit properties create two Euclid spaces and one Euclid plane. One may conclude that the basic duality in biology – and in logic – has a materialistic foundation in the structure of symbols. If we consider that female and male versions exist, that breathing in and breathing out are processes with two partly contradicting goals, that our perception uses the contrast between two versions of the same reality, and that in physics two slightly contradicting basic units exist (proton, neutron), and that there are uncountable multitudes of instances of duality discovered by scientific thinking, one may well come to the conclusion that it is reasonable to assume the existence of *two* versions of one and the same concept of space. This will even more hold true in view of the multitudes of logical interconnections between the two.

The changes in perspectives create a space in which the changes can take place, but this space is not one but two sub-spaces, connected by a plane. This interpretation shows the DNA to be a logical plane (length and width) which is inseparable from two versions of itself in which a third dimension has been made visible.

This person regrets the constraints of space which make it virtually impossible to package more aspects and perspectives into the present project proposal.

Summary

The present project proposal calls the Reader's attention to following points:

- the natural reproduction of humans uses the interplay between sequenced and non sequenced – commutative - assemblies' numerical properties;
- the upper limit for the information carrying capacity of a commutative assembly is given by $I_{comm}=\text{part}(n)^{\ln \text{part}(n)}$ where part(*n*) refers to the number of partitions of *n*;
- the main technique genetics uses is splitting and fusing of assemblies, thereby arriving at cardinalities of maximally structured sets that are within or outside the boundaries 32..97; outside there is more space, inside the boundaries there is more matter, logically;
- the problems Readers had in connection with understanding and putting to good use of this fundamental logical dynamism arising from the duality: *sequenced-commutative* have been traced back in the human brain's artefact of perceiving similarities;
- the *dissimilarities* are expressed by building the differences *b-a, 2a-b, 2b-a, 2a-3b, 2b-3a.* One may call these the *simple, double* or *triple* differences. Double and triple differences have *left* and *right* varieties;
- Genetics uses a small detail, namely that difference which distinguishes e.g. 2+4 from 1+5, etc., the *place* of the cut;

- When asked by providers of venture capital, what one does, one may answer: “We count *more exactly – by a factor of ca. 0.3E10-93 %* - by not neglecting that detail that we were instructed at Elementary School to neglect” and
- “It appears Nature shamelessly and uninhibitedly utilises that very-very small little slack, which is indeed of a limited practical relevance, which distinguishes e.g. 3+3 from 2+4” and
- “No matter who says what, there is a difference between 1+1+1+1 and 2+2, because in 1+1+1+1 there are 3 cuts on the interval and in 2+2 there is only one, and cuts do count, if one wants to count really exactly” and
- “Not neglecting a detail that was traditionally neglected is usually a Good Thing.”

Acknowledgements

Thanks are due to colleagues Péter Borzsák and Iván Davidov, both of Vienna, for their collaborations.

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Closing Remarks

Project Proposal

This publication has the goal of finding partners for project.

The task is to

- host a mathematical table
- allow users to expand the table
- allow users to attach comments to the table.

The Table itself is like a stem-cell, insofar as it is presently small but can evolve in many ways and forms and become a huge organism.

The Table is in its basic version 136 rows and 81 columns and there exist 1260 varieties of it (9!/4!3!2!). There are implicated sub-tables involved which can get rather complicated and need programming effort.

The paper discusses the overall principles of the usage of the Table and gives some definitory suggestions to readings of the numbers contained.

The Reader is advised to construct his own Table to work along the argumentation of the paper. Suggestions, alternative ideas and additions are equally welcome and should be posted as comments on a website containing the Table available to the members of FIS.

ARTIFICIAL INTELLIGENCE AND UNRESOLVED SCIENTIFIC PROBLEMS

Alexander V. Sosnitsky

Abstract: *The connection of the AI problem with the group of actual unresolved scientific problems generated by latent fundamental crisis owing to general nonlegitimacy of modern Science is investigated. It is shown that such problems are solvable only jointly and their instrument is the part of AI. The legitimizing universal theory (model) of the World and the World phenomena on the basis of harmonious representations in which all the variety of the World can be essentially formally deduced from the most general properties of the World in the form of objective system of World definitions (concepts, abstracts) is developed. If such model was earlier used for a manual deduction of concepts, then the foundations for their formal generation are investigated in the given paper. The structure, components, development and comprehensive substantiation of such hypothetical model that already has a lot of theoretical and practical applications and prospects in many fields are considered.*

Keywords: *Uniform Formal Model of the World, Harmonious Information Cosmology, Science Legitimization, Harmonious Scientific Methodology, Harmonious Objective System of World Definitions, AI.*

ACM Classification Keywords*: H.0 Information systems – General*

Introduction. Actual Group of the United Scientific Problems

In the previous publications [Sosnitsky, 2008], [Sosnitsky, 2009] it was shown that Intelligence 1) has not been artificially created yet, 2) moreover, it has not even been defined, 3) cannot essentially be synthesized in the limits of modern Science, and 4) this problem is the consequence of existing fundamental drawbacks of Science. Though it is quite obvious and easily fills the entire observable World. The scheme of giving of an exact scientific definition of Intelligence has been shown and directions of its concretization from the position of the new concept of the Universe and harmonious information Cosmology were specified in those publications for the first time.

Taking into account that everybody has always dealt with the problems of thinking from the moment of Mankind appearance it is difficult to hope that at a certain moment a successful happy hacker, using the slackness of scientific authorities, can at last receive in some successful way the first full-fledged AI program as it was once with microcomputers. On the contrary, it is probably necessary to go carefully through all the steps of a complete way of difficult fundamental research and experimental developments that consistently improve scientific concepts and methodology up to the exhaustive knowledge of this phenomenon for this purpose. Every gap on this way essentially interferes with the achievement of full-fledged AI.

The last statement substantiates the purposeful order of scientific research. In the given paper the important organic connection of the problem of AI with the standing out group of fundamental unresolved scientific problems is investigated, each of which 1) also represents a pressing fundamental problem, 2) cannot be solved separately, 3) but only together with all the group, 4) their whole set forms an unprecedentedly difficult scientific barrier, 5) to overcome which some new radical ways must be applied.

This group, first of all, consists of the following problems (Fig. 1):

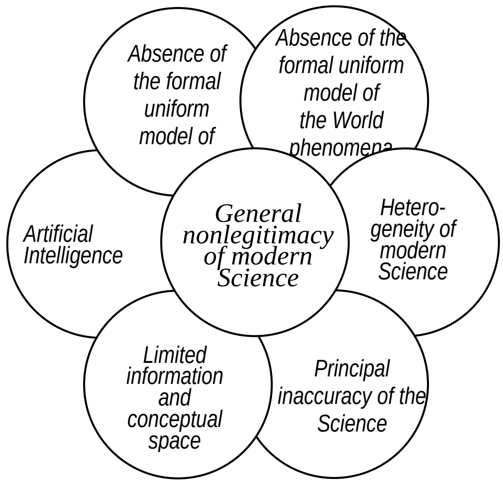

Figure 1. Actual Group of the United Scientific Problems

1. The absence of the uniform formal theory (model) of the World in modern Science. All the attempts of creation of such a theory have been unsuccessful so far. The last of them, synergy, observes new properties of Nature, but does not give the required model [Prigogine, 1990]. Therefore, the limited palliatives which do not meet the constantly growing requirements of Mankind− various fancies, folklore, mythologies, philology and philosophies are applied instead of them up to now. The expected theory must describe formally all the World as a whole, including its origin, organization, movement, purposes and the end which are projected then on the particular World phenomena. Concepts of formality and accuracy of the theory demand strict definitions, but we use the current general scientific ones so far.

2. The absence of the uniform formal theory of the World phenomena as the parts of the World. Intelligence is capable of working only with unified phenomena. Unification is reached by the restoration of both internal and external harmony of an abstract part of phenomena. The degree of formalization, unification, restoration and harmonization defines the degree of unity of the theory of phenomena. Its limit is the abstract of a phenomenon in the World Abstract Pyramid, and that abstract is deprived of all particular properties. Insufficient unification pulls phenomena apart in badly connected groups and destroys formalization up to zero, incapable to be processed in computers. Natural Intelligence is therefore unattainable because it uses independent but still unknown ways of internal formalization.

3. The heterogeneity of modern Science and division into insufficiently connected among themselves specialized sciences, each of which has to create its own internal instrument of formalization so that the results of sciences badly co-operate among themselves and that essentially limits Science development as a whole. And the more complex the branch is, the lower degree of formalization and lesser advance it makes, which is more supported by rather simple fields of Science for inanimate nature. Natural sciences and humanities are the first to be separated, and then the sciences inside these groups separate, etc. up to the outlooks of separate people. As a result of that against the background of high technologies Mankind produces bitter low-level conflicts inside and outside itself that are only capable of expanding in the specified conditions.

4. The limited information and conceptual space of Mankind. By definition the World is open well-written and completely cognizable book, which it is just necessary to be able to read. But human information remains a commodity and, therefore, a controllable resource. It is partially useful for information creation, but limits its consumption as a whole and contradicts the supreme laws of nature. The greatest obstacle is an insufficient universal system of concepts essentially limiting the perception of information by people, beginning with an inexact meaning of words even in the mother tongue and finishing with the last scientific reflections, the points of view, terminology, classifications and World outlooks. Today Science cannot move further only at the expense of some fields as it was not long ago but only together with many others that naturally leads to the above mentioned problems if an expert in a certain branch cannot receive the vitally important concepts of other branch and transfer his or her results to other fields. The typical example of the problem is that the papers of the author that can lead to important results do not get in existing scientific classifications for many years.

5. The inaccuracy of Science in principle. Each subject, including Mankind, always begins with zero and aspires to expand its constantly growing but finite knowledge of permanently changing infinite World as much as possible. The problem of the control of completeness and adequacy of knowledge to the World emerges as each deviation, even virtual, is negatively uncontrollable. Therefore, the certified theory of management of the World cognition, Science stabilization and evolution of the World models should be applied.

The specified seven problems, including AI and the nonlegitimacy of modern Science mentioned below, show that, in fact, for their solving it is necessary to reform all the established system of modern Science. In the next section it is shown that it is essentially completely illegitimate (inconsistent) in the sense that it has established itself.

The Problem of Definitions and General Nonlegitimacy of Modern Science

Definitions are the major fundamental part of Science, allowing to identify (the unique possession) and to classify (multiple possession) the World phenomena according to possession of some set properties in some functional (logic) dependence. Such a possession shows obligatory presence of some set of secondary properties in phenomena.

It is significant that this concept (the definition of definition) is impossible to explain precisely by classical Science because of indistinctness of initial concepts, for example, the concept of property. Therefore, we will consider only indisputable properties of definitions.

The definition (def e) of the World phenomenon (e) contains the left determinable part (in general case – the classifier) and the right part – correctly constructed formula (f) from definitions of the constituent parts (def e1, def e2, ..):

$$\text{def e} = \text{f}\left(\text{def e1: not def e1}\ (\text{e}, ..),\ \text{def e2: not def e2}\ (\text{e}, ..),\ ..\right),$$

so that the defined definition must not be in the right part in any way in order to avoid non-determinable tautology.

The application of this scheme of definition to the initial definitions (def e1, def e2, ..) generates the infinite recursion of definitions back that cannot be finished in any way by modern Science because of the absence of this mechanism. Hence, all the existing definitions are essentially illegal and, hence, all the system of Science is nonlegitimate by definition that is modestly hushed up by its apologists.

It becomes legitimate while finding some substantiated initial definitions, which explains the liking for axiomatic methods of scientific research based on some randomly chosen axioms, the validity of which is not called in question because is not discussed. They have led to the problems mentioned above.

Harmonious Information Cosmology and Science Legitimization

Statement of a problem is an initial part of the research; the second part is indication of directions of its solution. The deadlock is eliminated by a radically new model of the World on the basis of the complete system of the ideally harmonized original concepts deduced forward from the only initial Nothing concept that has an exact analytical expression. All of them have exact legitimate definitions and solve fully all the group of the above mentioned problems, actually laying down the foundations of new scientific Reformation.

Nothing is unstable and disharmonizes into internally existing infinite World, generating all its variety, including the mechanism of reverse harmonization in Nothing. The World is divided into abstract parts and real parts, Space-Time-Matter Complexes appear, the concepts of harmony, copying, relation, existence, movement, cognition, etc. are defined, the purposes of general and universal harmonization appear and five classes of entities (harmonizers) depending on the degree of harmonization of the axis of Time are consistently formed. In fact, the mechanism of natural appearance and development of harmonizers from the initial class (inanimate nature) in the highest class (Nothing) is designated. Intelligence (Life) is the third (intermediate) class of harmonizers which is followed by the two more. The basic mechanisms of thinking in systems with Time are deduced. It is possible to show that for each set of properties of the environment-subject couple there are limiting procedures of harmonization. Harmony is the Super Law of movement of entities in their interconnection.

Mankind is the collective Intelligence copying the World in the form of Science (Fig. 2), satisfying the initial conditions of the 1) external to the World and 2) internal consistency and 3) availability for all the particular subjects. Science is the copy (Knowledge) of the World, part which is orientated to the reception of new Knowledge (Methodology).

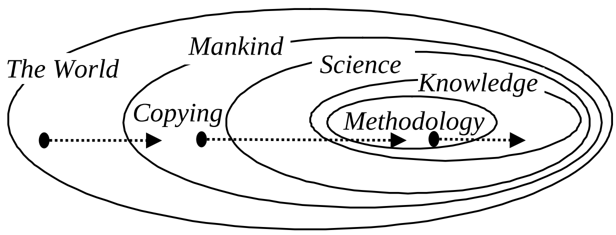

Figure 2. The World, Mankind and Science

Harmonious Decision of the Problem of Definitions

For the first time the harmonious World model has an exact initial concept and the mechanisms of deduction of all the derivative concepts up to the level of the Real World, which radically solves the problem of all the definitions and legitimizes Science for the first time.

Every World entity is a set of relations singled out by some other relation as a unit. At the real level they have seven types of components [Sosnitsky, 2008], [Sosnitsky, 2009]: 1-3) Space-Time-Matter (STM) Complex, 4) Relations (including enclosed entities), 5) Movement, 6) Laws, and 7) Purpose.

Every entity participates expressly or by implication in the infinite variety of internal and external incoming and outgoing relations, which can vary under the influence of the Time Complex. If there is sufficient harmonious potential, entities increase their motionless part (subject), and at the excess of neighbors' potential – set this part in motion and start searching for a better harmonious condition with the internal and external reorganization up to destruction and generation from its remnants of other more harmonious entities (process). Thus, the World is a branching set of temporarily existing harmoniously related and mutually turning processes with a gradually increasing subject part in the direction of general and complete Nothing harmony.

At every change of any relation a certain subject disappears and appears a new one, within the framework of which an exhaustive harmonization of external and internal relations take place up to its destruction by more harmonious neighbors. Such a subject (definition) defines basic harmonious properties of the corresponding process and centers all the entities of our World both abstract, and real ones (Fig. 3).

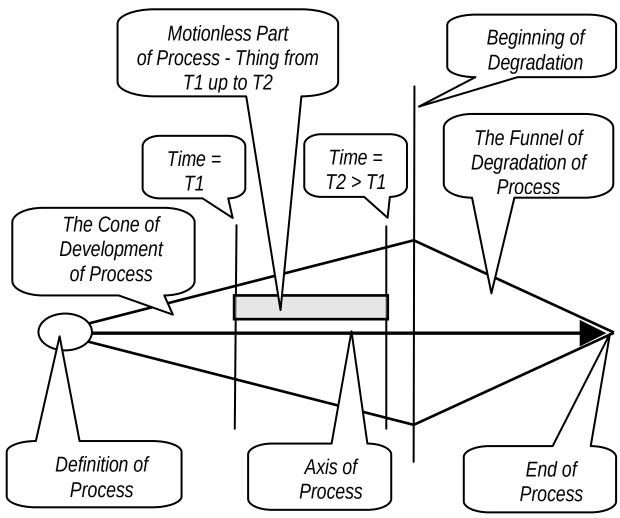

Figure 3. The General Structure of Processes in the Form of a Development-Degradation Cone

The difference of the harmonious system of definitions is their strict deductibility from the precisely defined initial Nothing concept. An objective pyramid of World definitions forming the required thesaurus originates from that. It is approximately represented by the subjective scientific system of definitions that was considered above.

The definitions that are above the Time-Complex are constant, those that are lower are divided into motionless (more high-level) and mobile (more low-level) parts. The motionless definitions define current properties (concepts and laws) of our World; however, there is a mechanism of their change.

Initial Principles of the Harmonic Theory

The formal World model must be deduced by the formal methodology from the level of the initial observing subject, the principles of which are substantiated in this section.

Absoluteness of the World

Absoluteness is the property of the uniqueness of the World and infinite plurality of all of its possible copies (Fig. 4). It follows from the definition of the World as a complete set of (directly and indirectly) related entities. All its copies are incomplete and different, but they are related through the only World original. It means that all logic deductions on different but correctly constructed copies can lead correctly to identical results like a conformity principle in modern physics [Feynman, 2005]. Strangely, but this condition is everywhere broken in modern Science based on axiomatic approaches [Chang, Keisler, 1990].

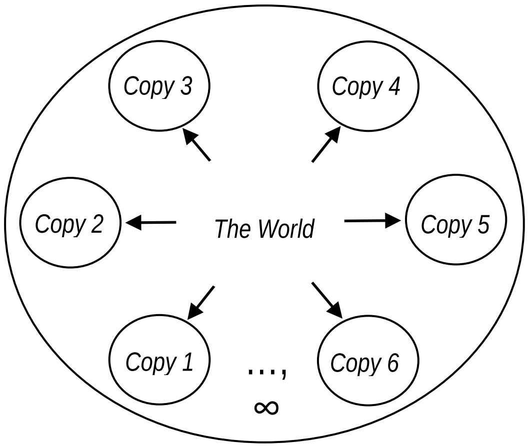

Figure 4. The Scheme of the Absoluteness of the World

Abstractness of the World

Abstractness means that our World has the abstract and real parts (Fig. 5). All the interactions take place in the real part, and the rules (laws) are established in the abstract part. The World is the process of a concretization of an initial Nothing abstract through the system of the Abstract Worlds (AW) in the Real World (RW) in the form of the World abstract pyramid (WAP). There is a mechanism of concretization of abstracts. The initial part of WAP is ideal, but beginning with the STM-Complex level the WAP becomes internally inconsistent and comes in the initial state of complete disharmonization (Chaos) with the subsequent harmonization under the control of WAP to the state of full Nothing harmony.

WAP is deduced from the only Nothing abstract in the form of a developing pyramid (a cone, etc., the names are allegorical) with final initial and infinite final parts. WAP has layers of relatively strongly related abstracts united in AW that have all the properties of the subWorlds. The abstracts are directly invisible at the real level, but there are mechanisms of their restoration from the observable real properties.

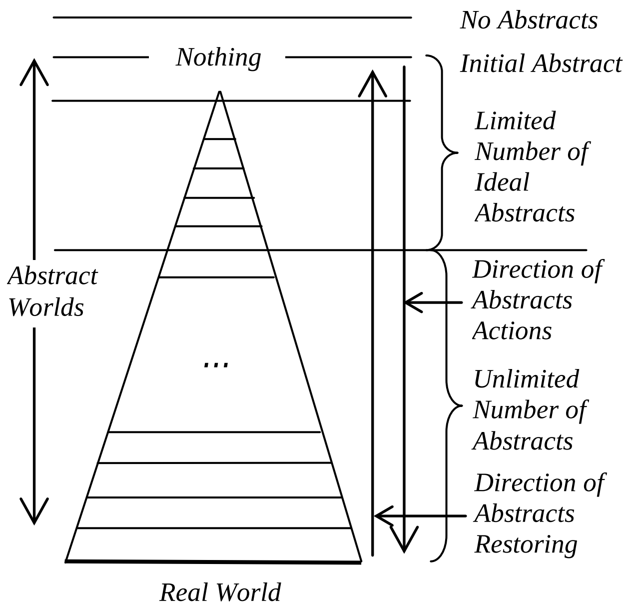

Figure 5. The Scheme of WAP

Cognoscibility of the World

Absolute cognoscibility means the possibility of complete copying of the infinite World, beginning with any of its real entity and zero state of knowledge (Fig. 6). According to the above mentioned definition it follows from the complete accessibility of all parts of the World and gives such basic possibility to all the subjects taking into account complete external connectivity and internal infinity of all the entities.

The real part of the World is directly observed, the abstract part is restored by the methodology specified below. Generally, the World cognition is restoration of WAP areas by means of the observed real bitmap.

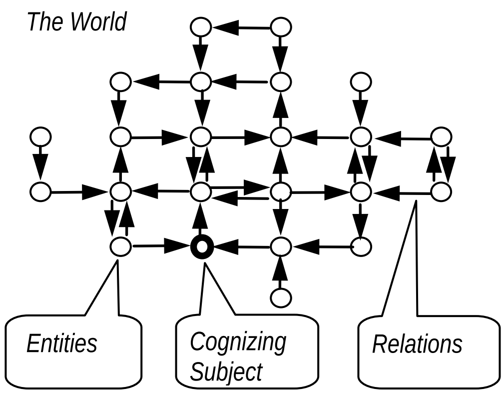

Figure 6. The Scheme of the Direct and Indirect Cognition of all the Entities of the World from any Subject

Harmonious Scientific Methodology

As well as any entity, the scientific methodology comes from the Super Law of Harmonization that aspires to establish every possible harmonious relation in the World. It produces consistently basic concepts of cognition (copying, communication, existence, cognition and further), which are in general presented in [Sosnitsky, 2008] and [Sosnitsky, 2009].

The second methodological level is formed of this Law by the three derivative basic methodologies of restoration of WAP phenomena (Fig. 7).

The initial abstract methodology is the process of restoration of abstracts through their repetition in related phenomena by means of separation of the general part, then through the separation of the general parts in the separated parts etc. upwards. We call it "dog methodology" by analogy with the experiments of a Russian academician Ivan Pavlov, the Nobel Prize winner who investigated conditioned reflexes on dogs [Pavlov, 1927]. It is natural that the accuracy of such a restoration is insignificant and applicable only to the phenomena with low-level purposes (dog entities).

However, multiple repetitions gradually increase a stable high-level system of abstracts, from which it is possible to deduce derivative abstracts. It can be used for separate considerable horizontal and vertical areas (God/dog methodology, God/dog entities).

While achieving the highest abstracts and cognizing the mechanisms of an exact deduction of derivative abstracts there arises the ultimate God methodology (the sense and form are opposite to the word "dog") for the phenomena with high-level purposes (God entities).

Then the derivative methodological levels follow concretised by the procedures described in [Sosnitsky, 2008], [Sosnitsky, 2009].

At the lower levels the processes become specific and have to synthesize themselves automatically by active harmonizers.

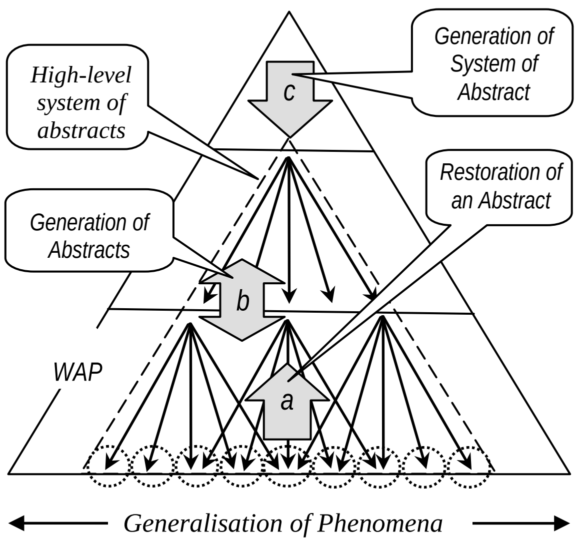

Figure 7. The Schemes of dog- (a), God/dog - (b) and God- (c) methodologies

Control of the Science Completeness

The harmonious theory gives the unique possibility of the control of integrity and completeness of scientific research by means of a full deduction of all the system of abstracts from the only initial abstract into extending in infinity WAP.

Two important possibilities follow from this:

1. The control of complexity of the infinite World and its phenomena by means of a choice of admissible for processing the final top parts of WAP without losing the most important relevant parts of the model (Fig. 8). Hence, the existence of the best model for every arising purpose follows from that. The World becomes small,

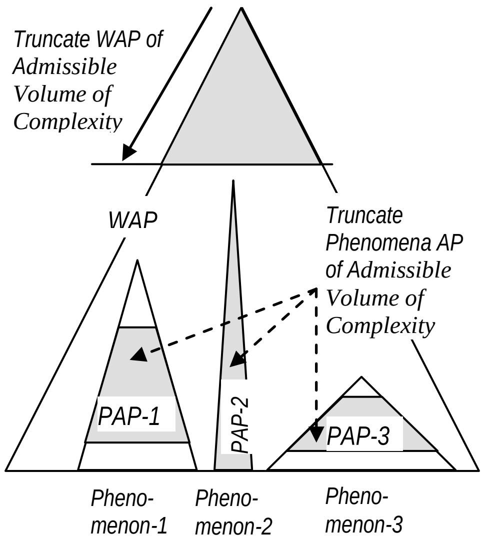

Figure 8. The Scheme of the Control of Complexity Volume of Phenomena (PAP) and the World AP (WAP) beginning with one point from what big technological conclusions follow

2. The control of the completeness of cognition of the World by means of a comparison of hypothetically deducible and available Knowledge that allows to discover some new both existing, and virtual future concepts and laws. The World becomes infinite in its virtual variations, but fuller and more stable in human perception. The possibility of stabilization of Science and succession of the World models and separate phenomena arises from here (Fig. 9).

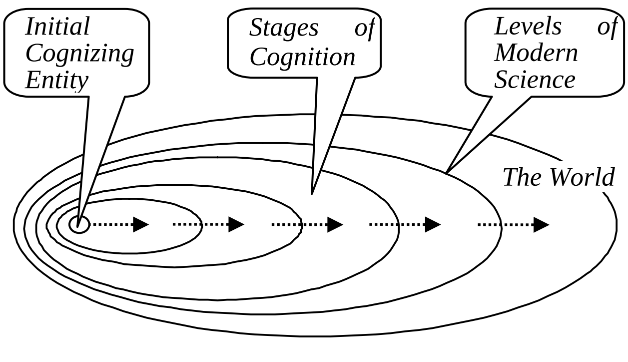

Figure 9. The Scheme of the Control of Integrity and Completeness of Scientific Research

Conclusion

As well as any final model, the given theory is not complete and remains hypothetical, as well as all modern sciences differing only in the degree of substantiation. However, the harmonious theory is for the first time integral and capable of defining all the arising actual concepts objectively. It discovers the new ways of solving actual problems, and now it already has numerous theoretical and practical applications and prospects in many areas. In fact, it prepares radical Reformation of all the system of modern Science [Kuhn, 1962].

In particular, for the first time it allowed to deduce an objective definition of Intelligence and to give a holistic specification of its basic properties and procedures. Moreover, the basic system of initial definitions of knowledge, including the concepts of existence, relation, information, knowledge, understanding, research, harmonization, etc. is deduced for this purpose.

In the given paper the substantiation of the theme is continued and (many unexpected) scientific fields connected with it are specified, the problems of which are subject to the preliminary solving to achieve full-fledged Intelligence: uniform formal World theories, universal formal modeling of the World phenomena, World copying, World abstracting, information cosmology, the theory of formalization, the objective system of definitions, the uniform scientific thesaurus, the integration of specialized sciences, the expansion of information and conceptual space, the objective uniform classifications, the uniform World outlook, the control of completeness of cognition, the management of the World cognition, the stabilization of Science and the evolution of World models.

It should also be noted that the given field of Science is undeservedly forgotten, probably because of its extreme complexity, so between the Ancient Greek thinkers [Aristotle, 1928] and the given research are not seen other similar papers in the field of the exact sciences.

Acknowledgement

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Major Fields of Scientific Research: Absolute Theories of the Universe, Reform of Science and new Scientific Methodologies, Artificial Intelligence

DISCRETE ARTIFICIAL INTELLIGENCE PROBLEMS AND NUMBER OF STEPS OF THEIR SOLUTION

Tatiana Kosovskaya

***Abstract**: Aggregate characteristics of discrete models appearing in different artificial intelligence problems are considered. It is shown that if an investigated object is a collection of its elements and its description contains properties of these elements and relations between them then a predicate calculus language is convinient for its simulation. In such a case a lot of problems are NP-hard. Upper bounds of steps for two essentially different decision algorithms are presented. A problem of transformation of an investigated object and the number of its decision steps is regarded. A many-level approach (consisting in the extraction of subformulas of goal conditions) to the decision of these problems is described. It allows to decrease the used time.*

***Keywords**: artificial intelligence, pattern recognition, analysis of situation, transformation, predicate calculus, complexity of algorithm.*

***ACM Classification Keywords**: I.2.4 ARTIFICIAL INTELLIGENCE Knowledge Representation Formalisms and Methods – Predicate logic, F.2.2 ANALYSIS OF ALGORITHMS AND PROBLEM COMPLEXITY Nonnumerical Algorithms and Problems – Complexity of proof procedures.*

Introduction

Algorithmical complexity of a lot of artificial intelligence problems permitting its simulation by means of predicate formulas is considered. Examples of such problems are: pattern recognition, chess and draught playing, market situation analysis, intelligent robot movement, medical diagnostics and treatment choice.

It is shown that for the most of the problems under consideration we can construct a model described by simple type predicate formulas. In such a case the problem decision is equivalent to the proof of a logical sequent of the form "If elementary conditions for an object are fulfilled then there exist a list of different in pairs values for variables such that the goal condition is valid for this list of values". Such a problem is NP-complete.

The upper bounds of step number of such a sequent proof are done for two different approaches. These bounds have different parameters in the exponent of the power. The number of a solution steps may be rather different in dependence of the chosen elementary features and the goal condition structure.

Problems in which an object may be transformed by means of an action from the done set of transformations are regarded. Examples of such problems are: recognition of a distorted image, the choice of a strategy in chess playing, the choice of an action upon the market objects to receive a favorable situation, the search of the intelligent robot movement sequence which carry it into the done position, medical treatment choice. To solve such a problem one can add descriptions of possible transformations to the premise of the main sequent.

Location of important parts of an object permits to decrease the used time because of not great complexity of such parts. A many-level approach to the solution of the described problems (consisting in the location of important parts with not great complexity of an object) is described.

Attributes in Discrete Simulation

The choice of initial attributes for description of an object for solving an artificial intelligence problem is the first stage of a discrete simulation of an informational process (representation of information for its further use). Examples of such attributes for rather different problems are as following.

1. Pattern recognition problems. Characteristics of the recognized objects or their parts are attributes in the terms of which a recognizable object and the classes of them are described.

2. Chess or draught games simulation. The state of a cell (what figure is situated in the cell) may be regarded as an attribute.

3. Market situation analysis. Qualitative and quantitative characteristics of a market participant are attributes.

4. Simulation of an intelligent robot movement. A graph of all possible pairwise connected situations of a robot may be a model for such a problem. A relation of two verteces to be adjoining and a property of a vertex to have a special mark may be regarded as an attribute.

5. Medical diagnostics. Symptoms of a patient are attributes.

Different researchers use different types of initial attributes representation to describe a model. But all of them have one common property – elementary character, i.e. the value of an attribute may be easily measured for every object of the model. Denote these attributes by

$$p_1, \dots , p_n .$$

Some examples of such types of attributes are the following.

– Propositional (boolean) variables (for problems 1, 5).

– Predicates describing properties of an object part or relations between them (for problems 1, 2, 3, 4, 5).

– Many-valued attributes having values from the done set D (for problems 1, 2, 3, 4, 5). Fuzzy and probabilistic characteristics may be regarded as many-valued attributes.

– Multi-sets of objects different parts of which have the same property and, consequently, this property must be presented in the object description several times (for problems 1, 4, 5).

– Graphs and marked graphs (for problems 1, 2, 3, 4).

All these types of attributes may be simulated by means of predicates.

– A boolean variable is a 0-ary predicate.

– To simulate a many-valued attribute $p(x)$ it is sufficient to have a predicate p' with an additional argument d: $p'(x,d) \Leftrightarrow p(x) = d$ (where $d \in D$).

– For a multi-set it is sufficient to have an additional integer argument in its characteristic function $\chi_A(x)$ which points out the number of appearance of the element x in the multi-set A: $p_A(x, n) \Leftrightarrow \chi_A(x) = n$.

– Graph $G = (V,E)$ may be represented by a set of atomic formulas with a binary predicate p defined by the equality $p(x,y) \Leftrightarrow (\{x,y\} \in E)$. To set a marked graph it is sufficient to have additional arguments for the marks.

Predicate formulas as a model for goal conditions

The definition of a goal condition providing the solution of a problem under consideration is the second stage of a discrete simulation of an informational process for an artificial intelligence problem.

Such a goal condition may be formulated in the terms of the chosen initial attributes and be written as such a formula $A(x)$ of a formalized language that if the formula $A(\omega)$ is valid for an investigated object ω then the problem has a positive solution. Moreover the goal condition may be represented by a quatifier-free formula in the form of disjunction of elementary conjunction of atjmic formulas.

For a lot of artificial intelligence problems it is important if there exists a part of the investigated object ω which satisfies the formula $A(x)$. Such a situation appears, for example, in the problem of a compound scene (it is denoted as ω) analysis which has several similar (from the same class) images situated in the different places of the scene: $\omega^1, \ldots, \omega^r$ such that $\omega^j \subset \omega$ and $A(\omega^j)$ is valid for all $j = 1, \ldots, r$.

While analysis of a market situation (ω is the whole market) there may appear several market participants or their collections $\omega^1, \ldots, \omega^r$ ($\omega^j \subset \omega$ for all $j = 1, \ldots, r$) such that every of them satisfies the same goal condition $A(\omega^j)$ for all $j = 1, \ldots, r$.

In the medical diagnostics problems (ω is a patient) there may be several parts

$$\omega^1, \ldots, \omega^r \ (\omega^j \subset \omega \text{ for all } j = 1, \ldots, r)$$

such that every of them satisfies the same or different goal conditions $A_1(\omega^1), \ldots, A_r(\omega^r)$.

This is the reason to represent the investigated object as a set of elementary objects $\omega = \{\omega_1, \ldots, \omega_\tau\}$. In such a case the attributes will be measured for the elements of the object and the goal condition will be represented by a formula with variables for elementary objects $A(x_1, \ldots, x_m)$ (or briefly $A(x)$ where x is a notation for the list of variables $x_1, \ldots, x_m$).

A description of an investigated object ω in the chosen model is a set of all properties of its elements and relations between them:

$$S(\omega) = \{p_1(\omega_1), \ldots, p_1(\omega_t), p_2(\omega_1), \ldots, p_n(\omega_i, \ldots, \omega_j)\}.$$

So the solution of the above mentioned problems may be reduced to the checking of a logical sequent of the form

$$S(\omega) \Rightarrow \Box x_{\neq} \ A(x), \qquad (1)$$

where $\exists x_{\neq}$ denotes “there exists a string of different in pairs values for the list of variables x”. For a lot of problems it is important not only to check out whether there exists a string of different in pairs values for variables x satisfying the formula $A(x)$ but to find such a string.

The proof of the logical sequent (1) is an NP-complete problem [Kosovskaya, 2007] and hence the determination of the string of different in pairs elementary objects satisfying the formula $A(x)$ is an NP-hard problem.

If a researcher proves that the logical sequent (1) may be checked out by an offered by him method in a polynomial (under notation lengths of a goal condition and an object description) number of steps then he will prove that $P \neq NP$ what is one of seven problems claimed to be the most complicated mathematical problems of the XXI century.

Methods of proof and upper bounds of their number of steps

Below for a step of computation we take a substitution of variable values into a formula $A(\mathcal{J})$ or a comparison of a conjunct of a formula $A(\mathcal{J})$ with a formula of the set $S(\omega)$ for their graphical coincidence.

The exhaustive search method has the upper bound of steps

$$O(t^m \|A\| \, \|S\|),$$

where $\|A\|$ is the number of atomic formulas in the formula $A(\mathcal{J})$, $\|S\|$ is the number of atomic formulas in the description $S(\omega)$ [Kosovskaya, 2007]. Note that this estimate coincides with the one for simulation of predicate approach to the artificial intelligence problems by boolean variables [Russel, 2003].

Logical methods (namely logical derivation in a sequent calculus [Kosovsky, 1981] or by resolution method [Russel, 2003]) has the upper bound of steps

$$O(s^a),$$

where s and a are the maximal number of occurrences of the same predicate in the description $S(\omega)$ and in the formula $A(\mathcal{J})$ respectively.

One can see that these estimates have different parameters in the exponent of the power. So a researcher may choose the method in applications in dependance of the structure of the attributes and the goal condition.

Actions upon an object involving transformation of its parts properties and relations

The solution of many problems assumes the existence of some actions upon an object which transform the initial properties of its elements and their relations.

Among the pattern recognition problems there is a problem of recognition of an object distorted by a transformation from a known set of transformations.

While simulation of chess game it is important not only to estimate a situation but to find a sequence of moves leading to a "successful" situation.

While projecting a model of intelligent robot movement it is required to construct a sequence of permutations providing a necessary position of it.

In the problem of the market situation analysis it is useful to find an action upon the market members leading to a required state of the whole market.

In the frameworks of a medical diagnostics problem a problem of treatment choice may be set up. It consists in the finding of such a sequence of medical actions upon a patient which transfer him to a state with the done condition (for example, to the class of practically healthy people).

To set an artificial intellegence problem dealing with a set of transformations acting an object it is important to know properties of such a set of transformations.

Let a collection of transformations be a group with a finite number of generatrices. The set of all generatrices will be denoted by $G = \{g_1, ..., g_T\}$ and the group itself by G^*.

Let the change of a single predicate or their couple value may be pointed out for every transformation g_j ($j = 1, ... ,T$) acting upon an investigated object. There may be several changes for every transformation g_j. Denote the number of such changes by l_j. These changes will be written down as an equivalences between attributes of objects ω and $g_j(\omega)$

$$B_j^l(\omega) \Leftrightarrow C_j^l(g_j(\omega)), \qquad (2)$$

where $B_j^l(\omega)$ and $C_j^l(g_j(\omega))$ are elementary conjunctions of atomic formulas, $l = l_1, \ldots, l_j$. An equivalence of the form (2) will be called a description of the transformation g_j and denoted by $\Gamma_j^l(\omega)$. The set of all descriptions of all transformations will be denoted by $\Gamma(\omega) = \{\Gamma_j^l(\omega_j^l) : j = 1, \ldots, T,\ l = 1, \ldots, l_j\}$.

The group properties of a transformation set (i.e. the existence of an inverse transformation for every one) are important if it is necessary not only to find such a transformation which transfers an object to a state satisfying the goal condition but to have an opportunity of its reverse transformation to the initial state.

For a lot of problems the group properties of a transformation set are not fulfilled. Chess game and choice of a medical treatment are examples of such problems. One deals only with a semigroup of transformations, i.e. a composition of allowed transformations is an allowed transformation. In such a case instead of equivalences in the form (2) we have only logical sequents

$$B_j^l(\omega) \Rightarrow C_j^l(g_j(\omega)), \qquad (2')$$

every of which will be also called a description of the transformation g_j and the set of all descriptions of all transformations will be denoted by $\Gamma(\omega) = \{\Gamma_j^l(\omega_j^l) : j = 1, \ldots, T,\ l = 1, \ldots, l_j\}$.

Transformation descriptions must be taken in account if an object may be changed by transformations from G^*. That is why the set of formulas $\Gamma(\omega)$ must be included to the formula (1). Let $\forall\sim\Gamma(\omega)$ be a closure of all formulas in $\Gamma(\omega)$ by an universal quantifier. Than we have a logical sequent

$$S(\omega)\ \Box{\sim}\Gamma(x) \Rightarrow \Box x_{\neq}\ A(x). \qquad (3)$$

In the case of an infinite G^* the problem of checking the logical sequent (3) is algorithmically undecidable. If G^* is finite and has R elements or the number of transformations acting an object is not more than R then the number of steps of checking the logical sequent (3) differs from the one for the logical sequent (1) by a multiplicative factor T^R, where T is the number of generatrices of G^* [Kosovskaya, 2009].

Multi-level approach to the decision of the formulated problems

Let $A_1(x_1), \ldots, A_K(x_K)$ be a set of goal conditions. Such a situation appears, for example, in pattern recognition problems every goal condition of which is a description of a class.

Find all subformulas $P_i^j(y_i^j)$ ($y_i^j \subseteq x^1 \cup \ldots \cup x^K$) with the "small complexity" which "frequently" appear in goal formulas $A_1(x_1), \ldots, A_K(x_K)$ and denote them by atomic formulas with new predicates p_i^j with new first-level arguments y_i^j for a list y_i^j of initial variables. Write down a system of equivalences

$$p_i^j(y_i^j) \Leftrightarrow P_i^j(y_i^j).$$

Let $A_k^1(x_k^1)$ be a formula received from $A_k(x_k)$ by substitution of $p_i^j(y_i^j)$ instead of $P_i^j(y_i^j)$. Here x_k^1 is a list of all variables in $A_k^1(x_k^1)$ including both some (may be all) initial variables of $A_k(x_k)$ and first-level variables appeared in the formula $A_k^1(x_k^1)$.

A set of all atomic formulas of the type $p_i^j(\omega_i^j)$ for which a formula $P(\tau_{ij}^1)$ (for some $\tau_{ij}^1 \subset \omega$) is valid is called a first-level object description and denoted by $S^1(\omega)$. Such a way extracted subsets τ_{ij}^1 are called first-level objects.

Repeat the above described procedure with formulas $A_k^1(x_k^1)$. After L repetitions L-level goal conditions in the following form will be received [Kosovskaya, 2008].

$$A_k^L(x_k^L)$$

$$p_1^1(y_1^1) \Leftrightarrow P_1^1(y_1^1)$$

$$\ldots$$

$$p_{n1}^1(y_{n1}^1) \Leftrightarrow P_{n1}^1(y_{n1}^1)$$

$$\ldots$$

$$p_i^l(y_i^l) \Leftrightarrow P_i^l(y_i^l)$$

$$\ldots$$

$$p_{nL}^L(y_{nL}^L) \Leftrightarrow P_{nL}^L(y_{nL}^L).$$

Such L-level goal conditions may be used for efficiency of an algorithm solving a problem formalized in the form of logical sequent (1).

To decrease the number of steps of an exhaustive algorithm (for every t greater than some t_0) with the use of 2-level goal description it is sufficient

$$n_1 t^r + t^{s1+n1} < t^m,$$

where r is a maximal number of arguments in the formulas $p_i^1(y_i^1) \Leftrightarrow P_i^1(y_i^1)$, n_1 is the number of first-level predicates, s^1 is the number of atomic formulas in the first-level description, m is the number of variables in the initial goal condition [Kosovskaya, 2008].

Analogous condition for decreasing the number of steps of a logical algorithm solving the problem (1) is

$$\Sigma_{k=1\ldots K} s^{ak} - \Sigma_{j=1\ldots n1} s^{\rho j} \geq \Sigma_{\kappa=1\ldots K} (s^1)^{ak1},$$

where a_k and a_k^1 are maximal numbers of atomic formulas in $A_k(x_k)$ and $A_k^1(x_k^1)$ respectively, s and s^1 are numbers of atomic formulas in $S(\omega)$ and $S(\omega) \cup S^1(\omega)$ respectively, ρ_j is the number of atomic formula in $P_i^1(y_i^1)$ [Kosovskaya, 2008].

Conclusion

The offered approach to the solution of artificial intelligence problems reduces them to the checking of a logical sequent (1). The problem (1) is NP-complete but different algorithms of its solution give different exponents in the upper bounds of their steps. An exhaustive algorithm is preferable if the number of variables in the goal condition is not great. If the number of atomic formulas in the goal condition is less then the number of its variables then the search of logical inference of (1) is preferable. These characteristics of the goal condition depend on the way of formalization of a problem.

In the framework of the offered approach it is possible to include descriptions of transformations acting upon an object into the main formula (1) and to receive the formula (3). Independently of the method used for (1) the number of steps of an algorithm solving the problem (3) increases in the same times.

Many-level approach to the description of goal conditions allows decreasing the number of steps of both an algorithm solving the problem (1) and an algorithm solving the problem (3). In such a case the term "small complexity" of an extracted formula means small number of variables in it if we use an exhaustive algorithm. The term "small complexity" of an extracted formula for an algorithm based on construction of a logical inference means small number of atomic formulas and decreasing the goal condition notation length after replacement the extracted formulas by atomic formulas with new first-level predicates.

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TABLE OF CONTENTS