Semiotics and Intelligent Systems Development: An Introduction

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Introduction

Sometimes, in order to mature, a methodology operates outside the mainstream for a period of time; it becomes the mainstream methodology only after this phase. This happened, for example, with neural networks, which appeared in the early 60's, but became the mainstream in research only 25 years later, after the development of the backpropagation algorithm as its learning algorithm. It happened also with fuzzy systems, which became popular only after the appearance of industrial fuzzy control applications in Japan. Likewise, an alternative approach is flourishing outside the mainstream, yet remain unknown to most researchers in AI (Artificial Intelligence) and IS (Intelligent Systems). This alternative approach is Computational Semiotics – and we argue that it is a rapidly evolving and maturing research field that could become the basic operational theory and method within AI and IS.

Semiotics is a field of research involved in the study of meaning processes and communication practices within the fields of the natural and social sciences, linguistics and philosophy. Ideas and concepts from semiotics are increasingly being used by different researchers in computer science as a source of both theoretical insights and practical methodology. In particular, we consider that the field of artificial intelligence (intelligent systems) could significantly benefit from the use of semiotic insights and methods. The interdisciplinary method of semiotics, applied to the investigation of sign processes and dedicated to the development of intelligent systems, is often referred to by the scientific community as *Computational Semiotics.* This approach proposes a new analysis and methodology to the study of intelligent control and intelligent systems, an approach based around an explicit account of the notion of the sign. This strategy has introduced a wealth of both theoretical and methodological tactics developed under the scope of semiotics, that are being used to enrich artificial intelligence and enable it to establish new frontiers and bridge the theoretical and methodological gaps that have disturbed artificial intelligence studies for quite some time.

Early attempts of interdisciplinary studies involving semiotics and intelligent systems were independently developed by researchers from Russia and the United States during the 60's and 70's. The original coverage of intelligent control theory by the Russian Dmitri Pospelov (Pospelov et.al. 1977; Pospelov 1991) is still almost completely unknown in western science. In the United States, a similar effort, also unknown to the mainstream, appeared in the work of Eugene Pendergraft (1993).

Despite being ignored for about twenty years, a new and growing interest in such an approach began to appear in the 1990's. In 1990, James Fetzer proposed using Peirce's philosophy of the sign as a strategy to deal with traditional problems in AI (Fetzer 1990). In

1991, James Albus published a seminal paper analyzing the properties and attributes of an intelligent system (Albus 1991). After 1995, the change began in earnest and many different conferences focused around the semiotic theory and method began to appear:

- Workshop on Architectures for Semiotic Modeling and Situation Analysis in Large Complex Systems, 10º IEEE International Symposium on Intelligent Control, Monterey, CA, 1995;
- Workshop on Control Mechanisms for Complex Systems: Issues of Measurement and Semiotic Analysis, Las Cruces, New Mexico, USA, 8-12 December 1996;
- Second Workshop on Applied Semiotics, Smolenice Castle Slovakia, 15 September 1997;
- ISAS'97 - Intelligent Systems and Semiotics - A Learning Perspective - International Conference - Gaithersburg, USA, 22-25 September 1997;
- ISIC/CIRA/ISAS'98 - IEEE International Symposium on Intelligent Control/ Computational Intelligence in Robotics and Automation/ Intelligent Systems and Semiotics - Gaithersburg, USA, 14-18 September 1998;
- ISIC/ISAS'99 - IEEE International Symposium on Intelligent Control, Intelligent Systems and Semiotics - Cambridge, MA - USA, 15-17 September 1999;

An important set of new research lines was developed at these meetings. Based on the work of Albus, Meystel started a new line of research interested in characterizing the basic behavior of intelligent systems, by means of a methodology called "multiresolutional semiotics". This line was systematized in two books: "Engineering of Mind" (Albus & Meystel 2001) and "Intelligent Systems - Architecture, Design and Control" (Meystel & Albus 2001). Other important contributions derived from these conferences were the work of Perlovsky on "Modeling Field Theory" (Perlovsky 2000); the work of Joslyn & Rocha on "Semiotics in Control Systems and Semiotic Agents" (Joslyn & Rocha 2000); the work of Rieger and his SCIPS - Semiotic Cognitive Information Processing Systems (Rieger 1999); the "stratified theory" approach of Prueitt in knowledge management and knowledge science (Prueitt 1999); and the "semiotic machines and knowbots" from Döben-Henisch et al. (2002).

All of these proposals emerged to form an innovative and novel background for intelligent systems research. However, most of them flourished as isolated efforts, without any connection with each other. The collation of all of them together, constituting a joint field of research, was one the greatest motivations for developing this book.

Organization of the Book

In this volume, our goal is to present the most representative research projects in Computational Semiotics at the present time. Considering the relevance of the semiotic approach for future developments in Artificial Intelligence, we suggest – and certainly hope – that the collection will be a major contribution to the field. Within the book, we have contributions from philosophers, cognitive scientists, computer scientists and engineers, all focused around the singular agenda of inquiring how semiotics works with intelligent system techniques to create newer and more robust types of intelligent systems. One of the main criticisms of which intelligent systems developers are accused, is being naïve in their approach to the question of ‘what is intelligence’. Therefore, it is as important to take into account the philosophy of the mind and to be aware of the issues of that field within current philosophic speculations, as it is to develop a practical methodology of the technologies of semiotic intelligent systems.

The book is divided into four parts. The first part, *Theoretical Issues*, includes articles with a more philosophical tone. The second part, *Discussions on Semiotic Intelligent Systems*, includes articles that still have a philosophical flavor, but move beyond philosophical speculations towards some kind of implementation of intelligent systems. The third part, *Semiotics in the Development of Intelligent Systems*, includes articles which use semiotics in some sense for the development of an intelligent system. Finally, the fourth part, *Semiotic Systems Implementations*, includes articles whose authors claim to be using semiotic concepts in intelligent systems implementation.

In his chapter, “Semiotic Brains and Artificial Minds - How Brains Make Up Material Cognitive Systems”, Lorenzo Magnani presents a new cognitive perspective on the role of external models and representations. This perspective is based on the process of the disembodiment of the mind, a process that can be understood to function as the basis of thinking abilities. He invokes Turing’s comparison between “unorganized” brains and “logical” and “practical” machines” to illustrate the centrality to cognition of this disembodiment of the mind, by examining the interplay between internal and external representations, both mimetic and creative. He describes the concept of what he calls a mimetic mind, emphasizing the possible impact of the construction of new types of universal “practical” machines, available in the environment, as new tools underlying the emergence of meaning processes.

In her chapter, “Morphological Semiosis”, Edwina Taborsky presents her account of reality as a semiotic system, operating as a complex network of continuous adaptive networked relations that produce spatiotemporal morphologies or signs. Using the triadic infrastructure of a sign, as developed by Charles Sanders Peirce, we are able to classify reality within different types of morphologies or phenomena. This abstract account of reality could provide the key for a future implementation of an intelligent system, able to fully represent each kind of phenomenon, according to its semiotic characteristics. This could provide the strategy for the construction of artificial systems that are able to fully “understand” and work with their surrounding reality. Even though the paper has a very abstract tone, this is a very important article, as it brings some light on how to connect the gap between general symbols or models and the particular actualities of the real world. At the end of the paper, she put forward some arguments on whether artificial (man-made) devices would possess the qualities for truly being called intelligent.

In her chapter, “The Semiotic Structure of Practical Reasoning Habits”, Phyllis Chiasson discusses how current intelligent systems lack that sort of commonplace, experience-based intelligence that helps ordinary humans get through ordinary days. Computers lack what can be defined as ‘common sense’. That explains why even the smartest computers are not as intelligent as we would expect or as we would wish them to be. She proposes a “theory of common sense” from which to extract programmable systems. Her chapter deals with the syntax of various common sense inferential structures and their effects upon the capacity to carry out and express practical reasoning. The author proposes that having information about how people actually do reason, regardless of language, intelligence, or education, may be of use for developing human-like computer models. In other words, she provides a new paradigm for thinking about thinking—one that many in the systems sciences may nevertheless recognize, whether or not he or she is familiar with a Peircean-like analysis.

In his chapter, “Toward a Pragmatic Understanding of the Cognitive Underpinnings of Symbol Grounding”, Ben Goertzel and collaborators describe some interesting and promising results on experiments that combine a systems theory of mind with pragmatic AI/machine-learning implementations. Even though their results are preliminary, their experiments address the important issue of “symbol grounding” – that is, the dynamics by which connections are made between abstract symbols and models, and concrete physical phenomena observed via sense perception and motor action. They developed a 3D simulated environment (AGI-SIM) as a medium for training, teaching and developing an integrative, general-intelligence-oriented AI software system, which they call the Novamente AI Engine. The role of the simulated embodiment is to assist Novamente in forming concrete sensorimotor groundings for abstract relationships, such as those expressed in English by prepositions and subject-argument relationships, and to provide a context in which these groundings may be used to bridge the gap between conceptual and sensorimotor knowledge in the context of learning to carry out simple tasks. Their work advocates an approach to symbol grounding that views the latter as one aspect of a more general and powerful process of integrated self-organizing cognition.

In his chapter, “Symbols: Integrated Cognition and Language”, Leonid Perlovsky proposes that a unifying mechanism, *Modelling Field Theory*, is behind the phenomena we identify as language and cognition. According to his approach, linguists often consider that language is made up of relationships among words and other linguistic entities, and as such, is separate from any relationship to the world. Mechanisms of language production in the mind and brain were always considered as detached and different from thinking and cognition. He argues that there are intrinsic mathematical mechanisms regulating concepts, emotions, and instincts, and that these operate as information processes in the mind related to perception and cognition. His approach tries to escape combinatorial complexity, something that became a plague within artificial intelligence in the past. He escapes combinatorial complexity by introducing a new type of logic, which he calls *Fuzzy Dynamic Logic*, which overcomes these past limitations. In addition, *Fuzzy Dynamic Logic* is related to emotional signals in the brain and is used to combine mechanisms of emotions and concepts. This approach unifies the abilities of language and cognition, playing an important role both in language acquisition and in cognitive ontogenesis. As such, his mathematical model of thought processes is directly related to the semiotic notions of signs, models and symbols.

In his chapter, “Natural Grammar”, Janos Sarbo and collaborators develop a semiotic analysis for what is going on during natural language use. His goal is to discover and examine the steps the mind or brain is going through when it is engaged in such a natural language use. He argues that it should be possible to develop a natural grammar which would formalize this “naturalness” in language use. He addresses these issues, while appealing to a more general understanding, that cognition should be modeled formally as a sign recognition process. He does so by investigating the complex relationship between computation and meaning. In summary, he proposes a model for knowledge representation which may be used, in the future, to allow a computer to generate information that a human user may process naturally.

In his chapter, “A Theory of Semantics Based on Old Arabic”, Tom Adi develops a theory of semantics using as a foundation his findings on the investigation of the meaning of short words in Old Arabic language. According to these findings, all Arabic vowels and consonants are equivalent to signs referring to abstract objects. He mapped 28 consonants and 4 vowels of Arabic to a 4x8 matrix of interrelated abstract objects and showed that, as a consequence, word roots could be seen as structured signs referring to structured abstract objects. On the one hand, this constitutes a theory of semantics for Old Arabic. On the other hand, Arabic roots provide an abstract set of concepts which any language could use to render reality. Based on these ideas, he developed a software system he called Readware which performs automated text exploration and analysis in English, German and French. His chapter explores the main ideas behind this system.

In their chapter, “The Semiotics Of Smart Appliances and Pervasive Computing, Peter Bøgh Andersen and Martin Brynskov apply the linguistic theory of semantic roles and the notions of signs, their referents, and their mode of signifying to the development of what they call *smart appliances*, or in other words, embedded intelligent systems. They discuss the notion of Digital Habitats, a conceptual and methodological framework for analyzing and designing smart appliances in the context of pervasive computing. They discuss and compare their approach to other approaches of developing intelligent systems. The main points in this comparison are: (a) the framework provides a description of action dependencies that is relatable to organizational concepts like qualifications and norms; (b) it can describe communicative as well as material acts and also the way they are linked; (c) it provides an explicit link between human activities and their spatial context; (d) it has an explicit dynamic model that precisely describes the conditions for executing actions; and (e) it offers a typology of participant roles, based on linguistic theory, that reduces complexity and therefore supports design processes.

In their chapter, “Systemic Semiotics as a basis for an Agent-Oriented Conceptual Modelling Methodology”, Rodney Clarke and collaborators use concepts from the field of systemic semiotics (most specifically the notion of genre) to derive an Agent-oriented Conceptual Modeling methodology for producing useful information systems. The goal is to emphasize the communicative, social and semiotic (meaning-making) processes that occur in organisations while designing the information system. They applied the Agent-oriented Conceptual Modeling framework i*, designed for use in early-phase requirements engineering, to a real world problem – developing a case study throughout the chapter. They also discuss some broader connections between systemic semiotics and agent-oriented systems.

In his chapter, “Computational Autognomics: An Introduction”, Jon Ray Hamann surveys the basic notions behind the concept of AutoGnome or “self-knowing” system, proposed during the 60ths and 70ths by Eugene Pendergraft and other collaborators, referred to at the beginning of this introduction. This chapter basically describes the AutoGnome as a semiotic machine which uses some of the philosophical principles of Charles Sanders Peirce. The main idea is the requirement for a strategy of theory formation. With that basis, the AutoGnome is able to create its own concepts based on input from the environment, and refine these concepts while it interacts with this same environment. At the end of the article, some applications using the AutoGnome are described and examined.

In his chapter, “What Makes A Thinking Machine? Computational Semiotics and Semiotic Computation”, Peter Krieg discusses the requirements for a “semiotic machine”. According to him, a “semiotic machine” must implement a genetic epistemology of cognition based on assimilation and pure relations. So, for him, semiotics is considered as a relational and ontogenetic approach to describing cognition and communication in signifying systems. Therefore, implementing a semiotic approach to computing requires a computable and scalable signifying space where signs can be arbitrarily related, interpreted, deliberated and produced. He argues that although signs are representations, a signifying space cannot be realized under the current representational paradigm of recording and processing static and physical data in a hierarchical data space. As an alternative to that paradigm, he introduces the ‘Pile’ system, which according to him meets those requirements of a ‘computable and scalable signifying space’ and is described as a ‘semiotic computation’ system structurally enabling processes of self-reflection, deliberation and interpretation, commonly associated with ‘thinking’.

Finally, in his chapter, “Reducing Negative Complexity by a Computational Semiotic System”, Gerd Doeben-Henisch describes the set-up for an experiment in computational semiotics. Starting with a hypothesis about negative complexity in the environment of human persons today, he proposes a strategy to assist in the reduction of this complexity by using a semiotic system. The basic ingredients of this strategy are a visual programming interface with an appropriate abstract state machine, which has to be realized by distributed virtual machines. The distributed virtual machines must be scalable, must allow parallel processing, must be fault tolerant, and should have the potential to work in real time. The objects to be processed by these virtual machines are logical models (LModels), which represent dynamic knowledge, including self learning systems. The descriptions are based on a concrete open source project he called Planet Earth Simulator.

Conclusions

What is the current stage of actual technology involving semiotics and intelligent systems? What are the open theoretical questions already addressed, but still in need of a more comprehensive analysis and better articulation?

The reader will find here a collection of texts that present, from different perspectives, a coordinated attempt to develop and correlate theoretical semiotics and AI techniques in order to create innovative and more robust intelligent systems. It is the first broad account of the field, it does not specifically focus on or privilege any of the different approaches that have been proposed up to now, but instead it gives the reader the opportunity to consider the various directions and focuses that are emerging within the field.

It is still too early to appropriately evaluate all the perspectives opened up by the frontier of research presented in this book. It is premature to assert that it constitutes a new scientific paradigm (a shift paradigm) with a new view of the established problems. What these perspectives have in common, however, is a focus on the basic principle of semiosis, which is that the mapping of input to output, or sensory stimuli to interpretation, is not a mechanical one-to-one linearity, but is instead, mediated by some ‘evolving intelligent process’. This focus on that triadic function and the varied analyses of the nature of that mediation as an ‘intelligent action of interpretation’, can be found in all the chapters in this book. There seems to be a consensus that many of the classic problems in AI (Brooks 1990; Harnad, 1990) are strongly connected to this fundamental issue of representation (semiotic process), and therefore, the new approaches and new technological offerings presented within this book constitute a “fresh breath” of ideas, and possibly an important new direction to follow in the future.

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