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**EDITORIAL: Cognitive Informatics: Exploring the Theoretical Foundations for Natural Intelligence, Neural Informatics, Autonomic Computing, and Agent Systems**

Yingxu Wang, Editor-in-Chief, University of Calgary, Canada

**Abstract:** Cognitive informatics (CI) studies the natural intelligence and internal information processing mechanisms of the brain, as well as the processes involved in perception and cognition. CI provides a coherent set of fundamental theories, and contemporary mathematics, which form the foundation for most information and knowledge-based science and engineering disciplines such as computer science, cognitive science, neuropsychology, systems science, cybernetics, computer/software engineering, and knowledge engineering. This editorial addresses the objectives of the International Journal of Cognitive Informatics and Natural Intelligence (IJCINI), and explores the domain of CI and its interdisciplinary nature. It clarifies the historical evolution of CI and its theoretical foundations. The coverage of this inaugural issue and recent advances in CI are reviewed. This editorial demonstrates that the investigation into CI will result in fundamental findings towards the development of next generation information and computing technologies.

**PAPER 1: Toward Theoretical Foundations of Autonomic Computing**

Yingxu Wang, University of Calgary, Canada

**Abstract:** Autonomic computing (AC) is an intelligent computing approach that autonomously carries out robotic and interactive applications based on goal- and inference-driven mechanisms. This article attempts to explore the theoretical foundations and technical paradigms of AC. It reviews the historical development that leads to the transition from imperative computing to AC. It surveys transdisciplinary theoretical foundations for AC such as those of behaviorism, cognitive informatics, denotational mathematics, and intelligent science. On the basis of this work, a coherent framework toward AC may be established for both interdisciplinary theories and application paradigms, which will result in the development of new generation computing architectures and novel information processing systems.

**PAPER 2: AURELLIO: A Cognitive Computational Knowledge Representation Theory**

Mehdi Najjar, University of Sherbrooke, Canada

André Mayers, University of Sherbrooke, Canada

**Abstract:** Encouraging results of the last few years in the field of knowledge representation within virtual learning environments confirm that artificial intelligence research in this topic finds it very beneficial to integrate the knowledge that psychological research has accumulated on understanding the cognitive mechanism of human learning and all the positive results obtained in computational modeling theories. This article introduces a novel cognitive and computational knowledge representation approach inspired by cognitive theories that explain the human

cognitive activity in terms of memory subsystems and their processes, and whose aim is to suggest formal computational models of knowledge that offer efficient and expressive representation structures for virtual learning. Practical studies both contribute to validate the novel approach and permit to draw general conclusions.

### **PAPER 3: Development of an Ontology for an Industrial Domain**

Christine W. Chan, University of Regina, Canada

**Abstract:** This article presents a method for ontology construction and its application in developing an ontology in the domain of natural gas pipeline operations. Both the method, as well as the application ontology developed, contribute to the infrastructure of Semantic Web that provides semantic foundation for supporting information processing by autonomous software agents. This article presents the processes of knowledge acquisition and ontology construction for developing a knowledge-based decision support system for monitoring and control of natural gas pipeline operations. Knowledge on the problem domain was acquired and analyzed using the Inferential Modeling Technique; then the analyzed knowledge was organized into an application ontology and represented in the Knowledge Modeling System. Since an ontology is an explicit specification of a conceptualization that provides a comprehensive foundation specification of knowledge in a domain, it provides semantic clarifications for autonomous software agents that process information on the Internet.

### **PAPER 4: Cognitive Processes by Using Finite State Machines**

Ismael Rodríguez, Universidad Complutense de Madrid, Spain

Manuel Núñez, Universidad Complutense de Madrid, Spain

Fernando Rubio, Universidad Complutense de Madrid, Spain

**Abstract:** Finite State Machines, in short FSMs, are formalisms that have been used for decades to describe the behavior of systems. They can also provide an intelligent agent with a suitable formalism for describing its own beliefs about the behavior of the world surrounding it. In fact, FSMs are the suitable acceptors for right linear languages, which are the simplest languages considered in Chomsky's classification of languages. Since Chomsky proposes that the generation of language (and, indirectly, any mental process) can be expressed through a kind of formal language, it can be assumed that cognitive processes can be formulated by means of the formalisms that can express those languages. Hence, we will use FSMs as a suitable formalism for representing (simple) cognitive models. We present an algorithm that, given an observation of the environment, produces an FSM describing an environment behavior that is capable to produce that observation. Since an infinite number of different FSMs could have produced that observation, we have to choose the most feasible one. When a phenomenon can be explained with several theories, Occam's razor principle, which is basic in science, encourages choosing the simplest explanation. Applying this criterion to our problem, we choose the simplest (smallest) FSM that could have produced that observation. An algorithm is presented to solve this problem. In conclusion, our framework provides a cognitive model that is the most preferable theory for the observer, according to the Occam's razor criterion.

## **PAPER 5: The OAR Model of Neural Informatics for Internal Knowledge Representation in the Brain**

Yingxu Wang, University of Calgary, Canada

**Abstract:** The cognitive models of information representation are fundamental research areas in cognitive informatics, which attempts to reveal the mechanisms and potential of the brain in learning and knowledge representation. Because memory is the foundation of all forms of natural intelligence, a generic model of memory, particularly the long-term memory, may explain the fundamental mechanism of internal information representation and the forms of learning results. This article presents the Object-Attribute-Relation (OAR) model to formally represent the structures of internal information and knowledge acquired and learned in the brain. The neural informatics model of human memory is introduced with particular focus on the long-term memory. Then, the OAR model that explains the mechanisms of internal knowledge and information representation in the brain is formally described, and the physical and physiological meanings of this model are explained. Based on the OAR model, knowledge structures and learning mechanisms are rigorously explained. Further, the magnitude of human memory capacity is rigorously estimated on the basis of OAR, by which the memory capacity is derived to be in the order of  $10^{8,432}$  bits.

## **PAPER 6: Constructivist Learning During Software Development**

Václav Rajlich, Wayne State University, US  
Shaochun Xu, Laurentian University, Canada

**Abstract:** This article explores the non-monotonic nature of the programmer learning that takes place during incremental program development. It uses a constructivist learning model that consists of four fundamental cognitive activities: absorption that adds new facts to the knowledge, denial that rejects facts that do not fit in, reorganization that reorganizes the knowledge, and expulsion that rejects obsolete knowledge. A case study of an incremental program development illustrates the application of the model and demonstrates that it can explain the learning process with episodes of both increase and decrease in the knowledge. Implications for the documentation systems are discussed in the conclusions.