Preface

Cognitive informatics (CI) is a new discipline that studies the natural intelligence and internal information processing mechanisms of the brain, as well as the processes involved in perception and cognition. CI was initiated by Yingxu Wang and his colleagues in 2002. The development and the cross fertilization among computer science, information science, cognitive science, and intelligence science have led to a whole range of extremely interesting new research fields known as CI, which investigates the internal information processing mechanisms and processes of the natural intelligence – human brains and minds – and their engineering applications in computational intelligence.

The theories of informatics and their perceptions on the object of information have evolved from the classic information theory, modern informatics, to cognitive informatics in the last six decades. The *classic information theories*, particularly Shannon's information theory, are the first-generation informatics that study signals and channel behaviors based on statistics and probability theory. The *modern informatics* studies information as properties or attributes of the natural world that can be distinctly elicited, generally abstracted, quantitatively represented, and mentally processed. The first- and second-generation informatics put emphases on external information processing, which are yet to be extended to observe the fundamental fact that human brains are the original sources and final destinations of information. Any information must be cognized by human beings before it is understood, comprehended, and consumed. The aforementioned observations have led to the establishment of the third-generation informatics, *cognitive informatics*, a term coined by Yingxu Wang in a keynote to the First IEEE International Conference on Cognitive Informatics in 2002. It is recognized in CI that *information* is the third essence of the natural world supplementing to matter and energy, which is any property or attribute of the natural world that can be distinctly elicited, generally abstracted, quantitatively represented, and mentally processed. On the basis of the evolvement of intension and extension of the term information, *informatics* is the science of information that studies the nature of information, its processing, and ways of transformation between information, matter, and energy.

In many disciplines of human knowledge, almost all of the hard problems yet to be solved share a common root in the understanding of the mechanisms of natural intelligence and the cognitive processes of the brain. Therefore, CI is a discipline that forges links between a number of natural science and life science disciplines with informatics and computing science. 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.

This book entitled **Developments in Natural Intelligence Research and Knowledge Engineering** is the fourth volume in the IGI Series of Advances in Cognitive Informatics and Natural Intelligence. The book encompasses 22 chapters of expert contributions selected from the *International Journal of Cognitive Informatics and Cognitive Computing* during 2010. The book is organized in five sections on: (i) Cognitive informatics; (ii) Cognitive computing; (iii) Denotational mathematics; (iv) Computational intelligence; and (v) Applications in cognitive informatics and cognitive computing.

SECTION 1. COGNITIVE INFORMATICS

Cognitive Informatics (CI) is a transdisciplinary enquiry of computer science, information science, cognitive science, and intelligence science that investigates into the internal information processing mechanisms and processes of the brain and natural intelligence, as well as their engineering applications in cognitive computing. Fundamental theories developed in CI covers the Information-Matter-Energy-Intelligence (IME-I) model, the Layered Reference Model of the Brain (LRMB), the Object-Attribute-Relation (OAR) model of internal information representation in the brain, the cognitive informatics model of the brain, natural intelligence (NI), abstract intelligence (αI), neuroinformatics (NeI), denotational mathematics (DM), and cognitive systems. Recent studies on LRMB in cognitive informatics reveal an entire set of cognitive functions of the brain and their cognitive process models, which explain the functional mechanisms and cognitive processes of the natural intelligence with 43 cognitive processes at seven layers known as the sensation, memory, perception, action, meta-cognitive, meta-inference, and higher cognitive layers.

According to CI, natural intelligence, in the narrow sense, is a human or a system ability that transforms information into behaviors; while in the broad sense, it is any human or system ability that autonomously transfers the forms of abstract information between data, information, knowledge, and behaviors in the brain. The history of human quest to understand the brain and natural intelligence is certainly as long as human history itself. It is recognized that artificial intelligence is a subset of natural intelligence. Therefore, the understanding of natural intelligence is a foundation for investigating into artificial, machinable, and computational intelligence.

The section on cognitive informatics encompasses the following four chapters:

- Chapter 1. *Perspectives on Cognitive Informatics and Cognitive Computing*
- Chapter 2. *The Cognitive Process of Comprehension: A Formal Description*
- Chapter 3. *A Hybrid Genetic Algorithm Based Fuzzy Approach for Abnormal Retinal Image Classificatio*n
- Chapter 4. *Logical Connections of Statements at the Ontological Level*

Chapter 1, **Perspectives on Cognitive Informatics and Cognitive Computing**, by Yingxu Wang, George Baciu, Yiyu Yao, Witold Kinsner, Keith Chan, Bo Zhang, Stuart Hameroff, Ning Zhong, Chu-Ren Hunag, Ben Goertzel, Duoqian Miao, Kenji Sugawara, Guoyin Wang, Jane You, Du Zhang, and Haibin Zhu, presents *cognitive informatics* as a transdisciplinary enquiry of computer science, information sciences, cognitive science, and intelligence science that investigates into the internal information processing mechanisms and processes of the brain and natural intelligence, as well as their engineering applications in cognitive computing. *Cognitive computing* is an emerging paradigm of intelligent computing methodologies and systems based on cognitive informatics that implements computational intelligence by autonomous inferences and perceptions mimicking the mechanisms of the brain. This chapter reports a set of collective perspectives on cognitive informatics and cognitive computing, as well as their applications in abstract intelligence, computational intelligence, computational linguistics, knowledge representation, symbiotic computing, granular computing, semantic computing, machine learning, and social computing.

Chapter 2, **The Cognitive Process of Comprehension: A Formal Description**, by Yingxu Wang and Davrondzhon Gafurov, presents comprehension as an ability to understand the meaning of a concept or the behavior of an action. Comprehension is an important intelligent power of abstract thought and reasoning of humans or intelligent systems. It is highly curious to explore the internal process of comprehension in the brain and to explain its basic mechanisms in cognitive informatics and computational intelligence. This chapter presents a formal model of the cognitive process of comprehension. The mechanism and process of comprehension are systematically explained with its conceptual, mathematical, and process models based on *the Layered Reference Model of the Brain* (LRMB) and the Object-Attribute-Relation (OAR) model for internal knowledge representation. Contemporary denotational mathematics such as concept algebra and Real-Time Process Algebra (RTPA) are adopted in order to formally describe the comprehension process and its interaction with other cognitive processes of the brain.

Chapter 3, **A Hybrid Genetic Algorithm based Fuzzy Approach for Abnormal Retinal Image Classification**, by J. Anitha, C. Kezi Selva Vijila, and D. Jude Hemanth, presents fuzzy approaches as one of the widely used artificial intelligence techniques in the field of ophthalmology. These techniques are used for classifying the abnormal retinal images into different categories which assist in treatment planning. The main characteristic feature which makes the fuzzy techniques highly popular is their accuracy. But, the accuracy of these fuzzy logic techniques depends on the expertise knowledge, which indirectly relies on the input samples. Insignificant input samples may reduce the accuracy that further reduces the efficiency of the fuzzy technique. In this work, the application of Genetic Algorithm (GA) for optimizing the input samples is explored in the context of abnormal retinal image classification. Abnormal retinal images from four different classes are used in this work. A comprehensive feature set is extracted from these images. Classification is performed with the fuzzy classifier and also with the GA optimized fuzzy classifier. Experimental results suggest highly accurate results for the GA based classifier than the conventional fuzzy classifier.

Chapter 4, **Logical Connections of Statements at the Ontological Level**, by Cungen Cao, Yuefei Sui, and Yu Sun, presents that in classical formal logics, negation can only be applied to formulas, not to terms and predicates. In (frame-based) knowledge representation, an ontology contains descriptions of individuals, concepts, and slots; and statements about individuals, concepts, and slots. The negation can be applied to slots, concepts, and statements, so that the logical implication should be considered for all possible combinations of individuals, concepts, slots, and statements. Hence, the logical implication at the ontological level is different from that at the logical level. This chapter attempts to give such logical implications between individuals, concepts, slots, statements, and their negations.

SECTION 2. COGNITIVE COMPUTING

Computing systems and technologies can be classified into the categories of *imperative*, *autonomic,* and *cognitive* computing from the bottom up. The imperative computers are a passive system based on stored-program controlled behaviors for data processing. The autonomic computers are goal-driven and self-decision-driven machines that do not rely on instructive and procedural information. Cognitive computers are more intelligent computers beyond the imperative and autonomic computers, which embody major natural intelligence behaviors of the brain such as thinking, inference, and learning.

Cognitive Computing (CC) is a novel paradigm of intelligent computing methodologies and systems based on CI that implements computational intelligence by autonomous inferences and perceptions mimicking the mechanisms of the brain. CC is emerged and developed based on the multidisciplinary research in CI. The latest advances in CI and CC, as well as denotational mathematics, enable a systematic solution for the future generation of intelligent computers known as *cognitive computers* (CogCs) that think, perceive, learn, and reason. A CogC is an intelligent computer for knowledge processing as that of a conventional von Neumann computer for data processing. CogCs are designed to embody *machinable intelligence* such as computational inferences, causal analyses, knowledge manipulation, machine learning, and autonomous problem solving.

The section on cognitive computing encompasses the following five chapters:

- Chapter 5. *The Event Search Engine*
- Chapter 6. *Incremental Knowledge Construction for Real-World Event Understanding*
- Chapter 7. *Autonomic Computing for a Complex Problem of Experimental Physics*
- Chapter 8. *On Hierarchical Content-Based Image Retrieval by Dynamic Indexing and Guided Search* 4-2
- Chapter 9. *Robust Feature Vector Set Using Higher Order Autocorrelation Coefficients* 4-3

Chapter 5, **The Event Search Engine**, by Takeshi Okadome, Yasue Kishino, Takuya Maekawa, Koji Kamei, Yutaka Yanagisawa, and Yasushi Sakurai, presents that in a remote or local environment where a sensor network always collects data produced by sensors attached to physical objects, the engine presented here saves the data sent through the Internet and searches for data segments that correspond to real-world events by using natural language (NL) words in a query that are input in an web browser. The engine translates each query into a physical quantity representation searches for a sensor data segment that satisfies the representation, and sends back the event occurrence time, place, or related objects as a reply to the query to the remote or local environment in which the web browser displays them. The engine, which is expected to be one of the upcoming Internet services, exemplifies the concept of symbiosis that bridges the gaps between the real space and the digital space.

Chapter 6, **Incremental Knowledge Construction for Real-World Event Understanding**, by Koji Kamei, Yutaka Yanagisawa, Takuya Maekawa, Yasue Kishino, Yasushi Sakurai, and Takeshi Okadome, presents that the construction of real-world knowledge is required if people are to understand real-world events that occur in a networked sensor environment. Since it is difficult to select suitable *events* for recognition in a sensor environment a priori, the authors propose an incremental model for constructing real-world knowledge. Labeling is the central plank of the proposed model because the model simultaneously improves both the ontology of real-world events and the implementation of a sensor system based on a manually labeled event corpus. A labeling tool is developed in accordance with the model and is evaluated in a practical labeling experiment.

Chapter 7, **Autonomic Computing for a Complex Problem of Experimental Physics**, by Tadeusz Wibig presents the standard experimental data analysis as based mainly on conventional, deterministic inference. The complexity of modern physics problems becomes nowadays so large that new ideas are highly appreciated. The chapter analyzes the problem of contemporary high-energy physics concerning the estimation of some parameters of the observed complex phenomenon. It confronts the natural and artificial networks performance with the standard statistical method of the data analysis and minimization. The general concept of the relations between CI and standard (external): classical and modern informatics was realized and studied by utilizing of Natural Neural Networks (NNN), Artificial Neural Networks (ANN), and MINUIT minimization package from CERN. The idea of autonomic computing was followed by using brains of high school students involved in our Roland Maze Project. Some preliminary results of the comparison are given and discussed.

Chapter 8, **On Hierarchical Content-Based Image Retrieval by Dynamic Indexing and Guided Search**, by Jane You, Qin Li, and Jinghua Wang, presents a new approach to content-based image retrieval by using dynamic indexing and guided search in a hierarchical structure, and extending data mining and data warehousing techniques. The proposed algorithms include: a wavelet-based scheme for multiple image feature extraction, the extension of a conventional data warehouse and an image database to an image data warehouse for dynamic image indexing, an image data schema for hierarchical image representation and dynamic image indexing, a statistically based feature selection scheme to achieve flexible similarity measures, and a feature component code to facilitate query processing and guide the search for the best matching. A series of case studies are reported, which include a wavelet-based image color hierarchy, classification of satellite images, tropical cyclone pattern recognition, and personal identification using multi-level palmprint and face features. The experimental results confirm that the new approach is feasible for content-based image retrieval.

Chapter 9, **Robust Feature Vector Set Using Higher Order Autocorrelation Coefficients**, by Poonam Bansal, Amita Dev, and Shail Jain, presents a feature extraction method that is robust to additive background noise for automatic speech recognition. Since the background noise corrupts the autocorrelation coefficients of the speech signal mostly at the lower orders, while the higher-order autocorrelation coefficients are least affected, this method discards the lower order autocorrelation coefficients and uses only the higher-order autocorrelation coefficients for spectral estimation. The magnitude spectrum of the windowed higher-order autocorrelation sequence is used here as an estimate of the power spectrum of the speech signal. This power spectral estimate is processed further by the Mel filter bank, log operation, and the discrete cosine transform to get the cepstral coefficients. These cepstral coefficients are referred to as the Differentiated Relative Higher Order Autocorrelation Coefficient Sequence Spectrum (DRHOASS). The authors evaluate the speech recognition performance of the DRHOASS features and show that they perform as well as the MFCC features for clean speech and their recognition performance is better than the MFCC features for noisy speech.

SECTION 3. DENOTATIONAL MATHEMATICS

The needs for complex and long-series of causal inferences in cognitive computing, αI, computational intelligence, software engineering, and knowledge engineering have led to new forms of mathematics collectively known as denotational mathematics. *Denotational Mathematics* (DM) is a category of expressive mathematical structures that deals with high-level mathematical entities beyond numbers and sets, such as abstract objects, complex relations, perceptual information, abstract concepts, knowledge, intelligent behaviors, behavioral processes, and systems.

It is recognized that the maturity of any scientific discipline is characterized by the maturity of its mathematical means, because the nature of mathematics is a generic meta-methodological science. In recognizing mathematics as the *metamethodology* for all sciences and engineering disciplines, a set of DMs has been created and applied in CI, αI, AI, CC, CogC, soft computing, computational intelligence, and computational linguistics. Typical paradigms of DM are such as *concept algebra* (Wang, 2008), *system algebra* (Wang, 2008), *real-time process algebra* (Wang, 2002), *granular algebra* (Wang, 2009), *visual semantic algebra* (Wang, 2009), and *inference algebra* (Wang, 2011). DM provides a coherent set of contemporary mathematical means and explicit expressive power for cognitive informatics, cognitive computing, artificial intelligence, and computational intelligence.

The section on denotational mathematics encompasses the following four chapters:

- Chapter 10. *A Web Knowledge Discovery Engine Based on Concept Algebra*
- Chapter 11. *Approximations in Rough Sets vs. Granular Computing for Coverings*
- Chapter 12. *Further Considerations of Classification-Oriented and Approximation-Oriented Rough Sets in Generalized Settings*
- Chapter 13. *Generalized Rough Logics with Rough Algebraic Semantics*

Chapter 10, **A Web Knowledge Discovery Engine Based on Concept Algebra**, by Kai Hu, Yingxu Wang, and Yousheng Tian, presents a system of autonomous on-line knowledge discovery and acquisition in cognitive informatics, cognitive computing, knowledge engineering, and computational intelligence. On the basis of the latest advances in cognitive informatics and denotational mathematics, this chapter develops a web knowledge discovery engine for web document restructuring and comprehension, which decodes on-line knowledge represented in informal documents into cognitive knowledge represented by concept algebra and concept networks. A visualized concept network explorer and a semantic analyzer are implemented to capture and refine queries based on concept algebra. A graphical interface is built using concept and semantic models to refine users' queries. To enable autonomous information restructuring by machines, a two-level knowledge base that mimics human lexical/syntactical and semantic cognition is introduced. The information restructuring model provides a foundation for automatic concept indexing and knowledge extraction from web documents. The web knowledge discovery engine extends machine learning capability from imperative and adaptive information processing to autonomous and cognitive knowledge processing with unstructured documents in natural languages.

Chapter 11, **Approximations in Rough Sets vs. Granular Computing for Coverings**, by Guilong Liu and William Zhu, presents rough set theory as an important technique in knowledge discovery in databases. Classical rough set theory proposed by Pawlak is based on equivalence relations, but many interesting and meaningful extensions have been made based on binary relations and coverings, respectively. This chapter makes a comparison between covering rough sets and rough sets based on binary relations. The authors also study the condition under which the covering rough set can be generated by a binary relation and the binary relation based rough set can be generated by a covering.

Chapter 12, **Further Considerations of Classification-Oriented and Approximation-Oriented Rough Sets in Generalized Settings**, by Masahiro Inuiguchi presents a view that rough sets can be interpreted in two ways: classification of objects and approximation of a set. From this point of view, classification-oriented and approximation-oriented rough sets have been proposed. In this chapter, the authors reconsider those two kinds of rough sets with reviewing their definitions, properties, and relations. They describe that rough sets based on positively and negatively extensive relations are mathematically equivalent, but it is important to consider both because the positively obtained and negatively extensive relations are not always in inverse relation in the real world. The difference in size of granules between union-based and intersection-based approximations is emphasized. Moreover, the types of decision rules associated with those rough sets are shown. The chapter shows the differences using a numerical example.

Chapter 13, **Generalized Rough Logics with Rough Algebraic Semantics**, by Jianhua Dai presents the collection of the rough set pairs <lower approximation, upper approximation> of an approximation (U, R) by a Stone algebra by defining two binary operators and one unary operator on the pairs. By introducing a more unary operator, one can get a regular double Stone algebra to describe the rough set pairs of an approximation space. Sequent calculi corresponding to the rough algebras, including rough Stone algebras, Stone algebras, rough double Stone algebras, and regular double Stone algebras, are proposed in this chapter. The sequent calculi are called rough Stone logic (RSL), Stone logic (SL), rough double Stone logic (RDSL), and double Stone Logic (DSL). The languages, axioms, and rules are presented. The soundness and completeness of the logics are proved.

SECTION 4. COMPUTATIONAL INTELLIGENCE

Intelligence science studies theories and models of the brain at all levels, and the relationship between the concrete physiological brain and the abstract soft mind. Intelligence science is a new frontier with the fertilization of biology, psychology, neuroscience, cognitive science, cognitive informatics, philosophy, information science, computer science, anthropology, and linguistics. A fundamental view developed in software and intelligence sciences is known as *abstract intelligence* (αI), which provides a unified foundation for the studies of all forms and paradigms of intelligence such as natural, artificial, machinable, and computational intelligence. αI is an enquiry of both natural and artificial intelligence at the neural, cognitive, functional, and logical levels from the bottom up. In the narrow sense, αI is a human or a system ability that transforms information into behaviors. However, in the broad sense, αI is any human or system ability that autonomously transfers the forms of abstract information between *data, information, knowledge,* and *behaviors* in the brain or intelligent systems.

Computational intelligence (CoI) is an embodying form of abstract intelligence (αI) that implements intelligent mechanisms and behaviors by computational methodologies and software systems, such as expert systems, fuzzy systems, cognitive computers, cognitive robots, software agent systems, genetic/evolutionary systems, and autonomous learning systems. The theoretical foundations of computational intelligence root in cognitive informatics, software science, and denotational mathematics.

The section on computational intelligence encompasses the following four chapters:

- Chapter 14. *Feature Reduction with Inconsistency*
- Chapter 15. *Learning Hierarchical Lexical Hyponymy*
- Chapter 16. *A New Quantum Evolutionary Algorithm with Sifting Strategy for Binary Decision Diagram Ordering Problem*
- Chapter 17. *A Robust Facial Feature Tracking Method Based on Optical Flow and Prior Measurement*

Chapter 14, **Feature Reduction with Inconsistency**, by Yong Liu, Yunliang Jiang, and Jianhua Yang, presents the feature selection as a classical problem in machine learning, and how to design a method to select the features that can contain all the internal semantic correlation of the original feature set is a challenge. The authors present a general approach to select features via rough set based reduction, which can keep the selected features with the same semantic correlation as the original feature set. A new concept named inconsistency is proposed, which can be used to calculate the positive region easily and quickly, with only linear temporal complexity. Some properties of inconsistency are also given, such as the *monotonicity of inconsistency,* et cetera. Then the authors propose three inconsistency based attribute reduction generation algorithms with different search policies. Finally, a *mini-saturation* bias is presented to choose the proper reduction for further predictive designing.

Chapter 15, **Learning Hierarchical Lexical Hyponymy**, by Jiayu Zhou, Shi Wang, and Cungen Cao, presents Chinese information processing as a critical step towards cognitive linguistic applications like machine translation. Lexical hyponymy relation, which exists in some Eastern languages like Chinese, is a kind of hyponymy that can be directly inferred from the lexical compositions of concepts, and of great importance in ontology learning. However, there is a key problem; the lexical hyponymy is so commonsense that it cannot be discovered by any existing acquisition methods. In this chapter, the authors systematically define lexical hyponymy relationship, its linguistic features, and propose a computational approach to semi-automatically learn hierarchical lexical hyponymy relations from a large-scale concept set, instead of analyzing lexical structures of concepts. This novel approach discovered lexical hyponymy relation by examining statistic features in Common Suffix Tree. Experimental results shows that the approach can correctly discover most lexical hyponymy relations in a given large-scale concept set.

Chapter 16, **A New Quantum Evolutionary Algorithm with Sifting Strategy for Binary Decision Diagram Ordering Problem**, by Abdesslem Layeb and Djamel-Eddine Saidouni, presents the quantum evolutionary quantum hybridization and its contribution in solving the binary decision diagram ordering problem. A problem formulation in terms of quantum representation and evolutionary dynamic borrowing quantum operators were defined. The sifting search strategy is used in order to increase the efficiency of the exploration process. Experiments on a wide range of data sets have shown the effectiveness of the proposed framework and its ability to achieve good quality solutions. The new proposed approach is distinguished by a reduced population size and a reasonable number of iterations to find the best order, thanks to the principles of quantum computing and to the sifting strategy.

Chapter 17, **A Robust Facial Feature Tracking Method Based on Optical Flow and Prior Measurement**, by Guoyin Wang, Yong Yang, and Kun He, presents cognitive informatics as a research area including some interdisciplinary topics. Visual tracking is not only an important topic in CI, but also a hot topic in computer vision and facial expression recognition. In this chapter, a novel and robust facial feature tracking method is proposed, in which Kanade-Lucas-Tomasi (KLT) optical flow is taken as basis, and the method of prior measurement consisting of pupils detecting, feature restricting, and errors accumulating is used to improve the predictions. Simulation experiment results show that the proposed method is superior to the traditional optical flow tracking. Furthermore, the proposed method is used in a real time emotion recognition system and good recognition result is achieved.

SECTION 5. APPLICATIONS OF COGNITIVE INFORMATICS AND COGNITIVE COMPUTING

A series of fundamental breakthroughs have been recognized, and a wide range of applications has been developed in cognitive informatics and cognitive computing in the last decade. This section reviews applications of theories, models, methodologies, mathematical means, and techniques of CI and CC toward the exploration of the natural intelligence and the brain, as well novel cognitive computers. The key application areas of CI can be divided into two categories. The first category of applications uses informatics and computing techniques to investigate cognitive science problems, such as memory, learning, and reasoning. The second category adopts cognitive theories to investigate problems in informatics, computing, and software/knowledge engineering. CI focuses on the nature of information processing in the brain, such as information acquisition, representation, memory, retrieve, generation, and communication. Through the interdisciplinary approach and with the support of modern information and neuroscience technologies, mechanisms of the brain and the mind may be systematically explored.

The section on applications of cognitive informatics and cognitive computing encompasses the following five chapters:

- Chapter 18. *Modeling a Secure Sensor Network Using an Extended Elementary Object System*
- Chapter 19. *Amplification of Signal Features Using Variance Fractal Dimension Trajectory*
- Chapter 20. *Some Remarks on the Concept of Approximations from the View of Knowledge Engineering*
- Chapter 21. *Giving Personal Assistant Agents a Case-Based Memory*
- Chapter 22. *An Evaluation Method of Relative Reducts Based on Roughness of Partitions*

Chapter 18, **Modeling a Secure Sensor Network Using an Extended Elementary Object System**, by Vineela Devarashetty, Jeffrey J.P. Tsai, Lu Ma, and Du Zhang, presents a sensor network consisting of a large number of sensor nodes, which are spread over a geographical area. Sensor networks have found their way into many applications, from military domains to traffic or environmental monitoring, to name a few. As sensor networks reach towards wide spread deployment, security becomes a major concern. Practitioners need to be sure about the confidentiality, authenticity, and tamper-proof features of data. The research thus far has focused on how to deploy sensor networks so that they can work efficiently. The focus of this chapter is on sensor networks' security issues. The authors propose a formal model to design and analyze the secure sensor network system. The model is based on an augmented Petri net formalism, called Extended Elementary Object System. This proposed secure sensor network model has a multi-layered structure consisting of sink node layer, sensor node layer and security mechanism layer. At the security mechanism layer, a synchronous firing mechanism is utilized as a security measure to detect malicious node attacks to sensor data and information flow. In addition, the model applies SNEP protocol for authentication and confidentiality of sensor data.

Chapter 19, **Amplification of Signal Features Using Variance Fractal Dimension Trajectory**, by Witold Kinsner and Warren Grieder, presents how the selection of parameters for the variance fractal dimension (VFD) multiscale time-domain algorithm can create an amplification of the fractal dimension trajectory that is obtained for a natural-speech waveform in the presence of ambient noise. The technique is based on the variance fractal dimension trajectory (VFDT) algorithm that is used not only to detect the external boundaries of an utterance, but also its internal pauses representing the unvoiced speech. The VFDT algorithm can also amplify internal features of phonemes. This fractal feature amplification is accomplished when the time increments are selected in a dyadic manner rather than selecting the increments in a unit distance sequence. These amplified trajectories for different phonemes are more distinct, thus providing a better characterization of the individual segments in the speech signal. This approach is superior to other energy-based boundary-detection techniques. These observations are based on extensive experimental results on speech utterances digitized at 44.1 kilosamples per second, with 16 bits in each sample.

Chapter 20, **Some Remarks on the Concept of Approximations from the View of Knowledge Engineering**, by Tsau Young Lin, Rushin Barot, and Shusaku Tsumoto, presents approximations in granular computing (GrC) vs. rough set theory (RS). Examples are constructed to contrast their differences in the Global GrC Model (2^{nd} GrC Model), which, in pre-GrC term, is called partial coverings.

Mathematically speaking, RS-approximations are “subbase” based, while GrC-approximations are “base” based, where “subbase” and “base” are two concepts in topological spaces. From the view of knowledge engineering, its meaning in RS-approximations is rather obscure, while in GrC, it is the concept of knowledge approximations.

Chapter 21, **Giving Personal Assistant Agents a Case-Based Memory**, by Ke-Jia Chen and Jean-Paul A. Barthès, presents Personal Assistant (PA) agents as cognitive agents capable of helping users handle tasks at their workplace. A PA must communicate with the user using casual language, sub-contract the requested tasks, and present the results in a timely fashion. This leads to fairly complex cognitive agents. However, in addition, such an agent should learn from previous tasks or exchanges, which will increase its complexity. Learning requires a memory, which leads to the two following questions: Is it possible to design and build a generic model of memory? If it is, is it worth the trouble? The chapter tries to answer the questions by presenting the design and implementation of a memory for PA agents, using a case approach, which results in an improved agent model called MemoPA.

Chapter 22, **An Evaluation Method of Relative Reducts Based on Roughness of Partitions**, by Yasuo Kudo and Tetsuya Murai, presents the rough set foundations of set-theoretical approximation of concepts and reasoning about data. The concept of relative reducts is one of the most important for rule generation based on rough set theory. In this chapter, from the viewpoint of approximation, the authors introduce an evaluation criterion for relative reducts using roughness of partitions constructed from them.

This book is intended to the readership of researchers, engineers, graduate students, senior-level undergraduate students, and instructors as an informative reference book in the cutting-edge fields of cognitive informatics, natural intelligence, abstract intelligence, and cognitive computing. The editor expects that readers of **Developments in Natural Intelligence Research and Knowledge Engineering** will benefit from the 22 selected chapters of this book, which represent the latest advances in research in cognitive informatics and natural intelligence and their engineering applications.

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