Convergence of Cognitive Informatics and Cybernetics—Guest Editorial on Special Issue on Cybernetics and Cognitive Informatics

***Abstract*—The three greatest theories in science and engineering developed in the 1940s are cybernetics, information theory, and systems theory. *Cybernetics* is the science of communication and control in humans, machines, organizations, and societies across the reductive hierarchy of neural, cognitive, functional, and logical levels. A contemporary form of cybernetics, known as cognitive informatics (CI), is a transdisciplinary inquiry of cognitive and information sciences that investigates into the internal information processing mechanisms and processes of the brain and natural intelligence and their engineering applications via an interdisciplinary approach. This special issue on cybernetics and CI focuses on the theme of "*convergence of CI* and *cybernetics*," which investigates the shared foundations of cybernetics and CI and their impacts on cybernetic and cognitive systems. This editorial demonstrates that the investigation into CI and cybernetics may encouragingly result in fundamental discoveries toward the development of next-generation intelligent systems and cognitive computing technologies.**

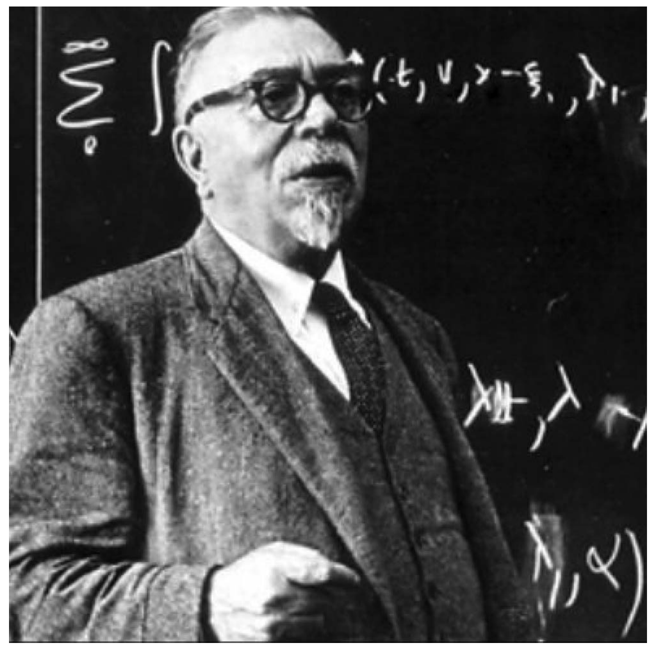
***Index Terms*—Abstract intelligence, cognitive informatics (CI), computational intelligence, cybernetics cognitive computing, denotational mathematics, natural intelligence.**

I. Contemporary Cybernetics

CYBERNETICS, delineated by Wiener in 1948, is the science of communication and autonomous control in both machines and living things. In his seminal work entitled *Cybernetics or Control and Communication in the Animal and the Machine* [43], Wiener initiated the field of cybernetics to provide a mathematical means for studying adaptive and autonomous systems. Cybernetics mimics information communicated in machines with that of the brain and nervous systems. It also attempts to elaborate human behavior by cybernetic engineering concepts [2], [3], [7]–[11], [14], [16], [18], [20], [42], [44], [48]. Cybernetics constitutes one of the roots of modern cognitive science and computational intelligence.

Definition 1: Cybernetics is the science of communication and control in humans, machines, organizations, and societies across the reductive hierarchy of neural, cognitive, functional, and logical levels.

Studies in cybernetics cover biologically, cognitively, and intelligently motivated computational paradigms such as vision, neural networks, genetic algorithms, fuzzy systems, autonomic systems, cognitive systems, computational intelligence, and robotics. The domain and architecture of contemporary cybernetics encompass a wide range of coherent fields from the machine, natural, and organizational intelligence to social



Norbert Wiener (1894–1964)

intelligence in the horizontal scopes and from the logical, functional, and cognitive models to neural (biological) models in the vertical reductive hierarchy. Therefore, cybernetics in nature is a multidisciplinary and transdisciplinary inquiry of cognitive information processing and autonomic systems.

The scope of contemporary cybernetics has been extended from mainly machine intelligence to natural, organizational, and societal intelligence. Its reductive framework has been enriched from logical and functional models to cognitive and neural models. A number of emerging fields have developed in cybernetics and closely related areas such as cognitive informatics (CI) [13], [24], [26], [29], [41], abstract intelligence [35], natural intelligence [27], computational intelligence [1], [12], [17], [22], [23], [30], [38], [40], autonomous agent systems [15], [36], and denotational mathematics for cybernetics [30].

II. CI

The theories of informatics and their perceptions on information as the object under study have evolved from the classic information theory to modern informatics and then to CI in the last six decades. *Classic information theories* [5], [21], particularly Shannon's information theory [21], known

Digital Object Identifier 10.1109/TSMCB.2009.2017294

as the first-generation informatics, study signals and channel behaviors based on statistics and probability theory. *Modern informatics* studies information as properties or attributes of the natural world that can be generally abstracted, quantitatively represented, and mentally processed. The first- and second-generation informatics put emphasis on external information processing, which overlooks the fundamental fact that human brains are the original sources and final destinations of information and that any information must be cognized by human beings before it is understood. This observation leads to the establishment of the third-generation informatics, known as *CI*, a term coined by Wang in 2002 [24].

Definition 2: CI is the transdisciplinary inquiry of cognitive and information sciences that investigates into the internal information processing mechanisms and processes of the brain and natural intelligence and their engineering applications via an interdisciplinary approach.

An intensive review on the *theoretical framework of CI* was presented in [29], which provides a coherent summary of the latest advances in the transdisciplinary field of CI and an insightful perspective on its future development. The latest advances of CI not only encompass a coherent set of theories for explaining the logical and cognitive mechanisms of abstract intelligence and computational intelligence but also result in plenty of engineering applications such as cognitive computers, machine learning systems, autonomous agent systems, and intelligent search engines. The theories and applications of CI are rigorously supported by new forms of mathematics, collectively known as denotational mathematics [30].

Definition 3: Denotational mathematics is a category of expressive mathematical structures that deals with high-level mathematical entities beyond numbers and sets, such as abstract objects, complex relations, behavioral information, concepts, knowledge, processes, and systems.

The emergence of denotational mathematics is driven by the practical needs in cybernetics, CI, computational intelligence, cognitive computing, software science, and knowledge engineering, because all these modern disciplines study complex human and machine behaviors and their rigorous treatments. These phenomena stem from the fact that new problems require new forms of mathematics [6], [19], [30], [45], [46] and the maturity of a scientific discipline is characterized by the maturity of its mathematical underpinnings [28], [30].

Typical forms of denotational mathematics are *concept algebra* [31], *system algebra* [32], [39], *real-time process algebra* (RTPA) [25], [33], [34], and *visual semantic algebra* (VSA) [37]. Among the four forms of denotational mathematics, *concept algebra* is designed to deal with the new abstract mathematical structure of concepts and their representation and manipulation in knowledge engineering. *System algebra* is created for the rigorous treatment of abstract systems and their algebraic relations and operations. RTPA is developed for algebraically denoting and manipulating system behavioral processes and their attributes. In addition, VSA is developed for the formal modeling and manipulation of abstract visual objects and patterns.

The key application areas of CI can be divided into two categories. The first category of applications uses informatics and computing techniques to investigate cybernetics and cognitive science problems such as abstract intelligence, memory, learning, and reasoning. The second category includes the areas that use cybernetic and cognitive theories to investigate problems in informatics, computing, software engineering, knowledge engineering, and computational intelligence. CI focuses on the nature of information processes in the brain, such as information acquisition, representation, memory, retrieval, creation, 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 within the framework of CI.

III. Convergent Framework of Cybenetics and CI

Among the three abstract scientific disciplines that emerged in the 1940s—cybernetics, information science, and system science—it was conventionally perceived that cybernetics is closer to system science than to information science. However, the descriptions provided in Sections I and II, particularly the emergence of CI, reveal that cybernetics is actually closer to information science supplement to system science. This notion leads to an interesting convergence between contemporary cybernetics and CI, as well as system science and intelligence science, in a systematic and transdisciplinary context.

The theme of this special issue in IEEE Transactions on Systems, Man, and Cybernetics (Part B) is on the "*convergence of CI* and *cybernetics*," which investigates the shared foundations of cybernetics and CI and their impacts on cybernetic and cognitive systems. This special issue focuses on the cognitive, functional, and logical levels of cybernetics that explain what the cognitive mechanisms of the brain are and how it processes cognitive information in cybernetic systems.

The convergent framework of the transdisciplinary field of CI and cybernetics mainly encompasses the following topic areas:

(A) **Fundamental Theories of Cybernetics and CI**

- Cybernetics in CI.
- CI for cybernetics.
- Denotational mathematics for CI/cybernetics.
- System algebra for modeling cybernetic system architectures.
- Process algebra for modeling cybernetic system behaviors.
- Cybernetics versus intelligence science.
- Abstract system theories.
- Cybernetic mechanisms shared by natural and machine intelligence.
- Neural models of knowledge.
- Neural models of intelligence.

(B) **Systems Shared in Cybernetics and CI**

- Cybernetic models of the brain.
- CI models of the brain.
- Hybrid man–machine systems.
- Distributed intelligent systems.
- Long-life-span systems.
- Knowledge systems.
- System models of memory.

- Cognitive agent systems.
- Autonomic learning systems.
- Cognition systems of web contents.
- Soft and granular computing.
- Autonomous agent systems.
- Machine learning systems.

IV. STRUCTURE OF THIS SPECIAL ISSUE

This special issue on *CI* and *cybernetics* presents the latest advances in cybernetics, CI, and computational intelligence [47]. This special issue includes nine papers on the following key areas of cybernetics and CI:

- The contemporary framework of cybernetics.
- The advances in CI and cognitive computing.
- The CI aspect of cybernetics.
- The computational intelligence aspect of cybernetics.
- Collaborative intelligent systems.
- Denotational mathematics for cybernetics.
- Software engineering and cybernetics.
- Granular computing and cybernetics.
- Multimodal biometric systems.
- Formal unification verification.
- Autonomous agent systems.
- Generalized competitive learning.
- Absorbing Markov chains.

The guest editors expect that readers of the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS will benefit from the papers presented in this special issue on theories, models, algorithms, and applications of contemporary cybernetics in general and CI, natural intelligence, and computational intelligence in particular.

ACKNOWLEDGMENT

The guest editors would like to thank all authors for submitting their interesting work. They are grateful to the reviewers for their great contributions to this special issue. They would like to express their sincere appreciation to the Editor-in-Chief of the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS (PART B), Prof. E. Santos, Jr., and to the former Editor-in-Chief, Prof. D. Cook, for their advice and support to this special issue. They would also like to thank the editorial staff of IEEE, particularly T. Martin and J. N. Cerra, for their professional work on this special issue.

YINGXU WANG, *Guest Editor*
Department of Computer Science (Visiting Professor)
Stanford University
Stanford, CA 94305-9010 USA
(e-mail: yingxuw@stanford.edu)

International Center for Cognitive Informatics
(ICfCI), Theoretical and Empirical Software
Engineering, Research Center (TESERC),
Department of Electrical and Computer Engineering,
Schulich School of Engineering
University of Calgary
Calgary, AB T2N 1N4 Canada
(e-mail: yingxu@ucalgary.ca)

WITOLD KINSNER, *Guest Editor*
Department of Electrical and Computer Engineering
University of Manitoba
Winnipeg, MB R3T 5V6 Canada
(e-mail: kinsner@ee.umanitoba.ca)

DU ZHANG, *Guest Editor*
Department of Computer Science
California State University
Sacramento, CA 95819-6021 USA
(e-mail: zhangd@ecs.csus.edu)

REFERENCES

[1] J. Albus, "Outline for a theory of intelligence," *IEEE Trans. Syst., Man, Cybern.*, vol. 21, no. 3, pp. 473–509, May/Jun. 1991.
[2] R. Ashby, *Design for a Brain*. London, U.K.: Chapman & Hall, 1952.
[3] W. R. Ashby, *An Introduction to Cybernetics*. London. U.K.: Chapman & Hall, 1956.
[4] J. S. Bayne, "Cyberspatial mechanics," *IEEE Trans. Syst., Man, Cybern. B, Cybern.*, vol. 38, no. 3, pp. 629–644, Jun. 2008.
[5] D. A. Bell, *Information Theory*. London, U.K.: Pitman, 1953.
[6] E. A. Bender, *Mathematical Methods in Artificial Intelligence*. Los Alamitos, CA: IEEE CS Press, 1996.
[7] D. J. Cook, "Defining the scope of SMCB," *IEEE Trans. Syst., Man, Cybern. B, Cybern.*, vol. 38, no. 1, pp. i–ii, Feb. 2008.
[8] R. C. Conant, "Laws of information which govern systems," *IEEE Trans. Syst., Man, Cybern.*, vol. SMC-6, no. 4, pp. 240–255, Apr. 1976.
[9] G. B. Fogel, E. Bullinger, S. F. Su, and F. Azuaje, "Special section on machine intelligence approaches to systems biology," *IEEE Trans. Syst., Man, Cybern. B, Cybern.*, vol. 38, no. 1, pp. 2–4, Feb. 2008.
[10] S. J. Heims, *John von Neumann and Norbert Wiener: From Mathematics to the Technologies of Life and Death*. Cambridge, MA: MIT Press, 1980.
[11] J. Johnston, *The Allure of Machinic Life: Cybernetics, Artificial Life, and the New AI*. Cambridge, MA: MIT Press, 2008.
[12] M. I. Jordan, "Computational intelligence," in *The MIT Encyclopedia of the Cognitive Sciences*, R. A. Wilson and F. C. Keil, Eds. Cambridge, MA: MIT Press, 1999, pp. i73–i80.
[13] W. Kinsner, "Towards cognitive machines: Multiscale measures and analysis," *Int. J. Cogn. Informatics Natural Intell.*, vol. 1, no. 1, pp. 28–38, 2007.
[14] N. Lindgren, "The birth of cybernetics—An end to the old world, the heritage of Warren S. McCulloch," *Innovation*, vol. 6, pp. 12–15, 1969.
[15] *Designing Autonomous Agents: Theory and Practice From Biology to Engineering and Back*, P. Maes, Ed. Cambridge, MA: MIT Press, 1991.
[16] *Purpose, Meaning, and Action, Control Systems Theories in Sociology*, K. A. McClelland and T. J. Fararo, Eds. New York: Palgrave Macmillan, 2006.
[17] A. M. Meystel and J. S. Albus, *Intelligent Systems, Architecture, Design, and Control*. Hoboken, NJ: Wiley, 2002.
[18] M. Pantic, A. Pentland, and A. Nijholt, "Special issue on human computing," *IEEE Trans. Syst., Man, Cybern. B, Cybern.*, vol. 39, no. 1, pp. 3–6, Feb. 2009.
[19] *Granular Computing: An Emerging Paradigm*, W. Pedrycz, Ed. Heidelberg, Germany: Physica-Verlag, 2001.
[20] E. Santos, Jr. and S. E. Shimony, "Deterministic approximation of marginal probabilities in Bayes nets," *IEEE Trans. Syst., Man, Cybern. A, Syst., Humans*, vol. 28, no. 4, pp. 377–393, Jul. 1998.
[21] *Automata Studies*, C. E. Shannon, Ed. Princeton, NJ: Princeton Univ. Press, 1956.
[22] A. M. Turing, "Computing machinery and intelligence," *Mind*, vol. 59, no. 236, pp. 433–460, Oct. 1950.
[23] J. von Neumann, *The Computer and the Brain*. New Haven, CT: Yale Univ. Press, 1958.
[24] Y. Wang, "Keynote: On cognitive informatics," in *Proc. 1st IEEE ICCI*, Aug. 2002a, pp. 34–42.

[25] Y. Wang, "The real-time process algebra (RTPA)," *Ann. Softw. Eng.: Int. J.*, vol. 14, no. 1–4, pp. 235–274, Dec. 2002b.

[26] Y. Wang, "On cognitive informatics," *Brain Mind: Transdisciplinary J. Neurosci. Neorophilisophy*, vol. 4, no. 3, pp. 151–167, 2003.

[27] Y. Wang, "Keynote: Cognitive informatics—Towards the future generation computers that think and feel," in *Proc. 5th IEEE ICCI*, Jul. 2006, pp. 3–7.

[28] Y. Wang, *Software Engineering Foundations: A Software Science Perspective*, CRC Book Series in Software Engineering, vol. II. New York: Auerbach, 2007a.

[29] Y. Wang, "The theoretical framework of cognitive informatics," *Int. J. Cogn. Informatics Natural Intell.*, vol. 1, no. 1, pp. 1–27, Jan. 2007b.

[30] Y.Wang, "On contemporary denotational mathematics for computational intelligence," *Transactions of Computational Science* pp. 6–20, June 2008a.

[31] Y. Wang, "On concept algebra: A denotational mathematical structure for knowledge and software modeling," *Int. J. Cogn. Informatics Natural Intell.*, vol. 2, no. 2, pp. 1–19, Apr. 2008b.

[32] Y. Wang, "On system algebra: A denotational mathematical structure for abstract system modeling," *Int. J. Cogn. Informatics Natural Intell.*, vol. 2, no. 2, pp. 20–42, Apr. 2008c.

[33] Y. Wang, "RTPA: A denotational mathematics for manipulating intelligent and computational behaviors," *Int. J. Cogn. Informatics Natural Intell.*, vol. 2, no. 2, pp. 44–62, Apr. 2008d.

[34] Y. Wang, "Deductive semantics of RTPA," *Int. J. Cogn. Informatics Natural Intell.*, vol. 2, no. 2, pp. 95–121, Apr. 2008e.

[35] Y. Wang, "On abstract intelligence: Toward a unified theory of natural, artificial, machinable, and computational intelligence," *Int. J. Softw. Sci. Comput. Intell.*, vol. 1, no. 1, pp. 1–18, Jan. 2009a.

[36] Y. Wang, "A cognitive informatics reference model of autonomous agent systems (AAS)," *Int. J. Cogn. Informatics Natural Intell.*, vol. 3, no. 1, pp. 1–16, 2009b.

[37] Y. Wang, "On visual semantic algebra (VSA): A denotational mathematical structure for modeling and manipulating visual objects and patterns," *Int. J. Softw. Sci. Comput. Intell.*, vol. 1, no. 4, pp. 1–12, 2009. to be published.

[38] Y. Wang, Y. Wang, S. Patel, and D. Patel, "A layered reference model of the brain (LRMB)," *IEEE Trans. Syst., Man, Cybern. C, Appl. Rev.*, vol. 36, no. 2, pp. 124–133, Mar. 2006.

[39] Y. Wang, L. A. Zadeh, and Y. Yao, "On the system algebra foundations for granular computing," *Int. J. Softw. Sci. Comput. Intell.*, vol. 1, no. 1, pp. 64–86, Jan. 2009.

[40] Y. Wang, W. Kinsner, and D. Zhang, "Contemporary cybernetics and its faces of cognitive informatics and computational intelligence," *IEEE Trans. Syst., Man, Cybern. B, Cybern.*, vol. 39, no. 4, pp. 1–11, 2009. to be published.

[41] Y. Wang, W. Kinsner, J. A. Anderson, D. Zhang, Y. Y. Yao, P. Sheu, J. Tsai, W. Pedrycz, J.-C. Latombe, L. A. Zadeh, D. Patel, and C. Chan, "A doctrine of cognitive informatics," *Fundam. Inform.*, vol. 90, no. 2, pp. 1–26, Feb. 2009.

[42] M. A. Wood and J. J. Bryson, "Skill acquisition through program-level imitation in a real-time domain," *IEEE Trans. Syst., Man, Cybern. B, Cybern.*, vol. 37, no. 2, pp. 272–285, Apr. 2007.

[43] N. Wiener, *Cybernetics or Control and Communication in the Animal and the Machine*. Cambridge, MA: MIT Press, 1948.

[44] N. Wiener, *The Human Use of Human Beings: Cybernetics and Society*. Boston, MA: Houghton Mifflin, 1950.

[45] L. A. Zadeh, "Fuzzy sets and systems," in *Systems Theory*, J. Fox, Ed. Brooklyn, NY: Polytechnic Press, 1965, pp. 29–37.

[46] L. A. Zadeh, "Fuzzy logic and approximate reasoning," *Synthese*, vol. 30, no. 3/4, pp. 407–428, Sep. 1975.

[47] *Proc. 6th IEEE International Conference on Cognitive Informatics (ICCI'07)*, D. Zhang, Y. Wang, and W. Kinsner, Eds. Lake Tahoe, CA: IEEE CS Press, Jul. 2007.

[48] F. Zhang, E. Santos, Jr., and P. B. Luh, "A performance study on a multiagent E-scheduling and coordination framework for maintenance networks," *IEEE Trans. Syst., Man, Cybern. C, Appl. Rev.*, vol. 37, no. 1, pp. 52–65, Jan. 2007.

Yingxu Wang (M'97–SM'04) received the B.Sc. degree in electrical engineering from Shanghai Tiedao University, Shanghai, China, in 1983 and the Ph.D. degree in software engineering from Nottingham Trent University, Nottingham, U.K., in 1997.

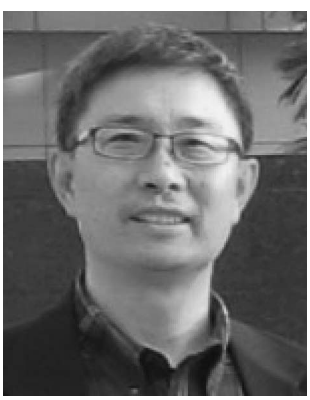
He has industrial experience since 1972 and has been a Full Professor with Lanzhou Jiaotong University, Lanzhou, China, since 1994. He was a Visiting Professor with the Computing Laboratory, Oxford University, Oxford, U.K., in 1995 and with the Department of Computer Science, Stanford University, Stanford, CA, and Berkeley Initiative in Soft Computing Laboratory, University of California, Berkeley, in 2008. He is currently a Professor of cognitive informatics and software engineering, the Director of the International Center for Cognitive Informatics, and the Director of the Theoretical and Empirical Software Engineering Research Center, Department of Electrical and Computer Engineering, Schulich School of Engineering, University of Calgary, Calgary, AB, Canada. He has authored or coauthored over 360 peer-reviewed journal and conference papers and 12 books in cognitive informatics (CI), software engineering, and computational intelligence. He is the founding Editor-in-Chief of the *International Journal of Cognitive Informatics and Natural Intelligence* and the *International Journal of Software Science and Computational Intelligence*. He is also the Editor-in-Chief of the *CRC Book Series in Software Engineering*. He is the initiator of a number of cutting-edge research fields or fundamental subject areas such as CI, abstract intelligence, denotational mathematics, cognitive computing, theoretical software engineering, coordinative work organization theory, deductive semantics, the layered reference model of the brain, the reference model of autonomous agent systems, cognitive complexity of software, and built-in tests.

Dr. Wang is an elected Fellow of the World Innovation Foundation, a Professional Engineer of Canada, a senior member of the Association for Computing Machinery, and a member of the International Organization for Standardization/International Electrotechnical Commission Joint Technical Committee 1 and the Canadian Advisory Committee for ISO. He is the Founder and Steering Committee Chair of the annual IEEE International Conference on CI. He is an Associate Editor for the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS—PART A: SYSTEMS AND HUMANS. He is a recipient of dozens of outstanding contributions, leadership, research achievements, best papers, and teaching awards for the last 30 years.

Witold Kinsner (S'72–M'73–SM'88) received the Ph.D. degree in electrical engineering from McMaster University, Hamilton, ON, Canada, in 1974.

He was an Assistant Professor in electrical engineering with McMaster University and McGill University, Montreal, QC, Canada. He is a cofounder of the first Microelectronics Centre in Canada and was its Director of Research from 1979 to 1987. He was also with the ASIC Division, National Semiconductor, Santa Clara, CA, designing configurable self-synchronizing CMOS memories. He is currently a Professor and an Associate Head with the Department of Electrical and Computer Engineering, University of Manitoba, Winnipeg, MB, Canada. He is also an Affiliate Professor with the Institute of Industrial Mathematical Sciences, University of Manitoba, and an Adjunct Scientist with the Telecommunications Research Laboratories, Winnipeg. He has been involved in research on algorithms and software/hardware computing engines for real-time multimedia, using wavelets, fractals, chaos, emergent computation, genetic algorithms, rough sets, fuzzy logic, and neural networks. The applications of his work included signal and data compression, signal enhancement, classification, segmentation, and feature extraction in various areas such as real-time speech compression for multimedia, wideband audio compression, aerial and space orthoimage compression, biomedical signal classification, severe weather classification from volumetric radar data, radio and power-line transient classification, image/video enhancement, and modeling of complex processes such as dielectric discharges. He also spent many years in VLSI design (configurable high-speed CMOS memories and magnetic bubble memories) and computer-aided engineering of electronic circuits (routing and placement for VLSI and field-programmable gate arrays). He is the author and a coauthor of more than 500 publications in the above areas.

Dr. Kinsner is a member of the Association for Computing Machinery, the Mathematical and Computer Modeling Society, and Sigma Xi. He is a Life Member of the Radio Amateurs of Canada.



Du Zhang (S'84–M'87–SM'99) received the Ph.D. degree in computer science from the University of Illinois, Chicago.

He is currently a Professor and the Chair of the Department of Computer Science, California State University, Sacramento. His current research interests include knowledge base inconsistency, machine learning in software engineering, and knowledge-based and multiagent systems. He is the author or a coauthor of more than 130 publications in journals, conference proceedings, and book chapters in these and other areas. He is currently an Associate Editor for the *International Journal on Artificial Intelligence Tools* and a member of the editorial board for the *International Journal of Cognitive Informatics and Natural Intelligence* and the *International Journal of Software Science and Computational Intelligence*. He has served as a Guest Editor for Special Issues of the *International Journal of Software Engineering and Knowledge Engineering*, the *Software Quality Journal*, *EATCS Fundamenta Informaticae*, and the *International Journal of Computer Applications in Technology*.

Dr. Zhang is a member of the Association of Computing Machinery (ACM). He has served as the Conference General Chair, the Program Committee Chair, a Program Committee Cochair, or a Program Area Chair for numerous IEEE international conferences. In addition, he has served as a Guest Editor for Special Issues of the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS—PART B.