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**Fuzzy Neural Computing Systems: Theory and Applications**  
**Tutorial for IEEE ICAL 2008**  
**Sunday, August 31, 2008**  
**3 Hours**

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**Abstract:** Fuzzy neural networks (FNNs), being the product of fuzzy logic and neural networks, are computational machines with unique capabilities for dealing with both numerical data and linguistic knowledge (fuzzy) information. In this tutorial, first we will provide an illustrative discussion on the biological basis of neural networks: learning from nature. Then we will continue our discussion on the basic notions, mathematical methodology and morphology, and learning and adaptation algorithms for static neural networks (SNNs). Also, some basic notions of conventional multilayered feedforward neural networks (MFNNs) with the well-known backpropagation (BP) learning algorithm will be discussed. This discussion will be illustrated by means of some examples taken from logic circuits, neuro-control systems, neuro-vision systems, pattern recognition, medical systems, and economics. Then we will discuss some advanced theory, with illustrative examples, of higher-order correlative neural networks (HOC-NNs). Then we will provide an extensive discussion on dynamic neural networks (DNNs) with applications to dynamic memory, control systems, vision systems, and robotics.

For developing FNNs, we will provide some necessary mathematical theory on fuzzy sets, fuzzy arithmetic, and fuzzy logic. Several fuzzy logic operations for various types of fuzzy neurons (FNs), which have fuzzy inputs and fuzzy weights, will be introduced. Analogous to the BP learning algorithm for MFNNs, the concepts and formulations of fuzzy backpropagation (FBP) learning algorithms for FNNs will then be developed. Moreover, the capabilities and limitations of FNNs consisting of many interconnected FNs will be discussed. The universal approximation capabilities of fuzzy basis function networks (FBFNs) that are represented as a modified version of Gaussian radial basis function networks (GRBFNs) will also be addressed. The material presented in this tutorial will not only provide an overview of the existing results, but also present some state-of-the-art achievements and open problems in the field of neural computing and fuzzy neural computing.

**Tutorial Outline:**

1. Introduction to Neural Networks: Biological Basis of Neural Networks
2. Morphology of Conventional Neural Networks
3. Learning and Adaptation for Neural Networks
4. Multilayered Neural Networks
5. Higher-Order Correlative Type of Neural Networks (HOC-NN)

6. Dynamic Neural Networks (DNN)
7. Learning and Adaptation for Fuzzy Neurons (FNs)
8. Fuzzy Sets, Fuzzy Arithmetic, and Fuzzy Logic: An Overview
9. Building Fuzzy Neurons (FNs) Using Fuzzy Arithmetic and Fuzzy Logic Operations
10. Conclusion

**Keywords:** fuzzy logic, neural networks, fuzzy neural networks, learning, universal approximation

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### **Biography of Dr. Madan M. Gupta:**



Dr. Madan M. Gupta is a professor emeritus in the Department of Mechanical Engineering and director of the Intelligent Systems Research Laboratory at University of Saskatchewan. Dr. Gupta's current research interests are in the areas of neuro-vision systems, neuro-control systems, integration of fuzzy-neural systems, neuronal morphology of biological vision systems, intelligent and cognitive robotic systems, cognitive information, new paradigms in information processing, and chaos in neural systems. He is also developing architectures of computational neural networks and computational fuzzy neural networks for application to advanced robotics, aerospace, and industrial systems.

Dr. Gupta has authored or coauthored over 800 published research papers. He recently coauthored the seminal book *Static and Dynamic Neural Networks: From Fundamentals to Advanced Theory*. Dr. Gupta previously coauthored *Introduction to Fuzzy Arithmetic: Theory and Applications*, the first book on fuzzy arithmetic, and *Fuzzy Mathematical Models in Engineering and Management Science*. Both of these books had Japanese translations. Also, Dr. Gupta edited 19 books in the fields of adaptive control systems, fuzzy computing, neuro-computing, neuro-vision systems, and neuro-control systems.

Dr. Gupta was elected fellow of the Institute of Electrical and Electronics Engineers (IEEE) for his contributions to the theory of fuzzy sets and adaptive control systems and for the advancement of the diagnosis of cardiovascular disease. He was elected fellow of the International Society for Optical Engineering (SPIE) for his contributions to the field of neuro-control and neuro-fuzzy systems. He was elected fellow of the International Fuzzy Systems Association (IFSA) for his contributions to fuzzy-neural systems. In 1991, Dr. Gupta was co-recipient of the Institute of Electrical Engineering Kelvin Premium. In 1998, Dr. Gupta received the Kaufmann Prize Gold Medal for research in the field of fuzzy logic. He has been elected as a visiting professor and a special advisor in the area of high technology to the European Centre for Peace and Development (ECPD), University for Peace, which was established by the United Nations.

Dr. Gupta received B.E. (Hons.) and M.E. degrees in electronics-communications engineering from the Birla Engineering College (now the Birla Institute of Technology & Science), Pilani, India, in 1961 and 1962, respectively. He received his Ph.D. degree from the University of Warwick, United Kingdom, in 1967 in adaptive control systems. In 1998, for his extensive contributions in neuro-control, neuro-vision, and fuzzy-neural systems, Dr. Gupta received an earned doctor of science (D.Sc.) degree from the University of Saskatchewan.

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### **Biography of Dr. Noriyasu Homma:**



Dr. Noriyasu Homma received a BA, MA, and PhD in electrical and communication engineering from Tohoku University, Japan, in 1990, 1992, and 1995, respectively.

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### **Biography of Ashu M. G. Solo:**



Ashu M. G. Solo is an electrical and computer engineer, mathematician, writer, and entrepreneur. His primary research interests are in new branches of math, intelligent systems, public policy, and the application of intelligent systems in control systems, computer architecture, power systems, optimization, pattern recognition, data mining, decision making, and public policy. Solo has about 100 publications in these and other fields. He co-developed

some of the best published methods for maintaining power flow in and multiobjective optimization of radial power distribution system operations using intelligent systems. He has served on 75 international program committees for 72 research conferences and 3 research multiconferences. Solo is the principal of Maverick Technologies America Inc. He previously worked in nine different research and development labs in universities and industry. Solo served honorably as an infantry officer and platoon commander understudy in the Cdn. Army Reserve.

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