GUEST EDITORIAL

Over the past few years, the development of intelligent decision-making techniques for complex systems has been significantly advanced by using fuzzy logic and neural network based methods. The application of fuzzy logic and neural networks has captured two of the essential features in human decision-making, i.e., the linguistic nature of knowledge representation, which facilitates the process of knowledge acquisition and transfer, and the learning nature of knowledge evolution, which leads to improvement in system performance and knowledge. This is due to the fact that, in fuzzy logic, linguistic variables are used as basic terms for knowledge descriptions, while in neural networks, learning algorithms are employed as the basic mechanism for universal approximation.

This special issue is dedicated to the applications of fuzzy logic and neural network techniques for solving real-world problems. Its purpose is to collect and disseminate some focused results of ongoing research and development efforts in these two methods, especially in their combinations. The decision to organize this special issue was made at the Fourth International Symposium on Robotics and Manufacturing (ISRAM '92) in Sante Fe, New Mexico. A call for papers resulted in 15 responses, from which the review process selected 7 for publication. The papers can broadly be classified into four categories: applications in robotic systems, industrial applications, inductive reasoning for fuzzy system design, and combination of fuzzy logic and neural networks.

The first paper, by Cao and Sanderson, introduces the concept of generalized fuzzy Petri nets (FPNs) and the reasoning structures of their transitions. The proposed FPN model uses three types of fuzzy variables, called local fuzzy variables, fuzzy marking variables, and global fuzzy variables, respectively, to describe uncertainty based on different aspects of fuzzy information. Analytical properties of several basic types of FPNs are presented in the paper. Applications of FPNs for modeling the incomplete, uncertain, and approximate information associated with firing of transitions and changing of states in robotic and manufacturing systems are illustrated in detail. A specific example of using FPNs for sensory transitions in a robotic system is provided.

The second paper, by Kumbla and Jamshidi, discusses the problem of hierarchical control of robotic manipulators using fuzzy logic. A decentralized hierarchical fuzzy control system for a robotic manipulator is implemented where kinematic control is treated as the supervisory mode at the higher level, while joint control is treated at the lower level. Each individual joint controller is implemented with fuzzy PD control. The inverse kinematic mapping which maps the Cartesian coordinates to the joint angles is determined by fuzzy logic based rules. Experimental results conducted on a Rhino robot indicates that, compared with traditional PD controllers, the fuzzy controller gives better performance over a typical operational range, and reaches the desired position with no overshoot.

The third paper, by Lever, Wang, Chen, and Shi, presents the recent results of their joint work on autonomous robotic mining excavation using fuzzy logic and neural networks for front-end-loader-type machines. To utilize the experience and expertise from skilled human operators, a behavior-control approach based on fuzzy logic is developed. Nine typical behavior programs for general excavation tasks are constructed and implemented with fuzzy logic rules. Two neural networks are built to assess excavation situations and then select the corresponding behavior programs based on force/torque feedback data. Simple strategies for self-evaluation and fusion of fuzzy behaviors are given. To verify the proposed approach, laboratory experiments are conducted using a PUMA 560 robot arm, a Zebra force/torque sensor, and a SUN workstation. Experimental results indicate that

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fuzzy behaviors are capable of reacting to unpredicted events during the excavation process and completing the desired excavation goals successfully.

The next two papers report two examples of using fuzzy logic for industrial process control. In the first example, Manikopoulos, Zhou, and Nerurkar present their work on the design and implementation of a fuzzy logic controller for a heat exchanger in a water-for-injection (WFI) system. Starting from an existing conventional PID controller implemented on a programmable logic controller (PLC), they design, test, and improve the rule base of a fuzzy controller to achieve superior system performance by utilizing additional low-cost sensing information in the heat-exchange process and its environment. A method of implementing fuzzy logic controllers with the PLCs is also discussed in this paper. In the second example, Baras and Patel describe a procedure of deriving decision rules for a fuzzy logic based PID turner for dominant-pole systems with large rise times and its applications in separator temperature and pH controls. They illustrate a method for using the inherent properties of typical systems to construct fuzzy logic rules for tuning PID gains without carrying out data analysis and parameter estimation, as in traditional methods. Their results show that the fuzzy logic rule base derived by the proposed method performs as desired. A surprising fact is that the resultant PID controller has a small derivative mode gain, which is advantageous since it prevents measurement noise from influencing the control actions. Furthermore, the fuzzy PID turner is seen to compensate, even when the controller gains no longer obey the order of magnitude estimates used in deriving the rule base, a clear demonstration of robustness.

The use of inductive reasoning to support the design of fuzzy controllers is investigated by Cellier and Mugica. A new methodology is introduced in their paper that allows on-line computation of a signal which is close to the optimal plant input as a function of plant inputs and outputs. This is carried out by creating a fuzzy logic based inductive-reasoning model for estimating the optimal plant input, which converts an open-loop design to an equivalent and more robust closed-loop design. To illustrate the validity of the proposed approach, an example is given in detail.

The last paper addresses the issue of integrating fuzzy logic methods with neural network techniques. Geng proposes a novel artificial neural network architecture called fuzzy CMAC neural network by revealing the inherent connection between cerebellar model arithmetic computer (CMAC) neural networks and fuzzy logic inference systems. The proposed architecture achieves a synergistic combination of the preferred features of a CMAC neural network and a fuzzy logic controller, and has significant potential in decreasing the cost, complexity, and learning time in network development over conventional neural networks. It not only retains the benefits of learning arbitrary functions through network training, but also captures the benefits of fuzzy logic which allows heuristic rules to be generated by experts using linguistic variables of meaning to the particular problem domain. A wide range of applications could be found for the proposed fuzzy CMAC networks.

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