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FUZZY LOGIC AND INTELLIGENT TECHNOLOGIES IN NUCLEAR SCIENCE (FLINS)

Background

FLINS, an acronym for Fuzzy Logic and Intelligent Technologies in Nuclear Science, launched in line with SCK•CEN's objective to give young talented people the opportunity to carry out future-oriented research. FLINS was initially built within one of the postdoctoral research projects at SCK•CEN in 1994.

Specific prototyping of fuzzy logic control (FLC) of the BR1 research reactor has been chosen as FLINS' first priority. With permission from the licensing body to perform the real FLC experiment on-line at BR1 for a limited time period (from September 1998 to September 1999), we succeeded all on-line experiments with FLC at the steady-state operation of BR1.

Objective

This R&D project for controlling the power level of the BR1 reactor started in 1995 and aims at investigating the added value of FLC for both the safety and economic aspects for a nuclear reactor control operation.

Programme

Fuzzy-logic control techniques are very mature in today's most engineering areas, but not in nuclear engineering. The main reason is that it is impossible to do experiments in nuclear engineering as easily as in other industrial areas. In the current project, we find that although there are already many fuzzy control applications, it is difficult for us to select the most suitable method for experiments at BR1 and to compare with some other algorithms. Moreover, due to the safety regulations of the nuclear reactor, it is not realistic to perform many experiments at BR1. In this situation, we have to conduct part of the pre-processing experiments outside the reactor, e.g., comparisons of different methods and the preliminary choices of the parameters. One solution is to make a simulation programme in a computer, but this has the disadvantage that the real time property cannot be well reflected. Therefore we adopted another strategy, that is, we designed and made a water-level control system, referred to as the demo model, which is suitable for our testing and experiments. In particular, this demo model (also see scientific report 1996, 1997, 1998) and is designed to simulate the power control principle of BR1.

To improve the existing system, we decided to go one step further in the use of fuzzy logic control: adaptive fuzzy logic control. In this type of control, the controller judges its performance and tries to improve it based on these performance results at each time step. However, our hardware could not handle this type of control due to its fixed structure, we were forced to write additional software on a PC.

First of all, we simulated the hydraulic behaviour of the demo model using ordinary differential equations. Using this simulation we could implement and test this control scheme. When these tests proved successful, we connected the real demo model to the PC and used the same control software. These enable us to easily adapt the control loop in a more flexible programming language than PLC code. In addition, when run on a modern PC, the simulations are a lot faster than the physical system, so it is easier to examine the influence of different parameters in the control loop. Our current research on the demo model can be widely used for educational purposes for those who are interested in intelligent systems with practical applications. Especially, any new control algorithm can be tested with this demo model. On the other hand, results from new algorithms can better serve for a real reactor control in the future.

Achievements

- All FLC on-line experiments at BR1 were successful within the period of obtained permission from AVN.
- Additional adaptive fuzzy control algorithm is implemented in a PC for the demo model and for the future BR1 fuzzy control.
- Part of the project results is in the progress of a European patent application.

Perspectives

Based on this successful project, we will extend our know-how on fuzzy logic expertise to some EU project proposals. We will start a new research project on development of intelligent systems for safeguards application at SCK•CEN.

Scientific partners

UG, Universiteit Gent (Gent, Belgium)

Scientific output

Books and book chapters

D. RUAN, Ed., "Fuzzy Systems and Soft Computing in Nuclear Engineering", Physica-Verlag, 1999, 479p.

D. RUAN AND A.J. VAN DER WAL, Guest editors, "Robotics Applications at FLINS'98, the special issue of Int. J. of Robotics and Autonomous Systems", Vol. 28, No. 1, Elsevier, 1999.

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D. RUAN, "Safety evaluation of nuclear transmission lines using fuzzy relations", in: N.E. Mastorakis, Ed., Computers and Computational Engineering in Control, 188-192, World Scientific Engineering Society Press, 1999.

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C. HUANG AND D. RUAN, "System analyse models for fuzzy risk estimation", in: L.A. Zadeh and J. Kacprzyk, Eds., Computing with Words in Information/Intelligent Systems 2, 195-220, Physica-Verlag, 1999.

International journals

C. ZHOU AND D. RUAN, "Integration of linguistic and numerical information for biped control, Int. J. of Robotics and Autonomous Systems", Vol. 28, No. 1, page 53-70, 1999.

X. LI AND D. RUAN, "Novel neural algorithms based on fuzzy _ rules for solving fuzzy relation equations: Part 2", Int. J. of Fuzzy Sets and Systems, Vol. 103, No. 3, page 473-486, 1999.

Conference proceedings

D. RUAN, "Safety regulations and fuzzy logic control to nuclear reactor", 1999 Eusflat-Estylf Joint Conference Proceedings, 59-62, September 22-25, Palma, Spain.

D. RUAN AND G. VAN DEN EYNDE, "Computer simulation of hydraulic analogy of a nuclear reactor with adaptive fuzzy control", Proceedings of International Workshop on Information and Communication Technology for Teaching and Training, 61-73, September 9-10, 1999, Gent, Belgium.

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D. RUAN, "On-line experiments of controlling nuclear reactor power with fuzzy logic", 1999 IEEE International Fuzzy Systems Conference Proceedings, Vol. 3, 1712-1717, August 22-25, 1999 Seoul, Korea.

D. RUAN, "Fuzzy logic and soft computing in nuclear engineering", Proceedings of the Eighth International Fuzzy Systems Association World Congress, Vol. 1, 325-329, August 17-20, 1999 Taipei, Taiwan ROC.

D. RUAN AND G. VAN DEN EYNDE, "Simulating an hydraulic analogy of a nuclear reactor and its adaptive fuzzy logic control", Proceedings of the 13th European Simulation Multiconference, Vol. II, 311-315, Warsaw, June 1-4, 1999.

Y. XU, D. RUAN, AND J. LIU, "Uncertainty automated reasoning in intelligent learning of soft knowledge", Proceedings of International Workshop on Information and Communication Technology for Teaching and Training, 29-45, September 9-10, 1999 Gent, Belgium.

Reports

D. RUAN, R. CARCHON, AND E.E. KERRE, "Aggregation operators: properties and applications, Task performed in the frame of the Belgian Support Programme to the IAEA for Safeguards implementation", SCK•CEN R-3331, 16p, April 1999..

G. VAN DEN EYNDE, D. RUAN, AND D. MARLOYE, "Fuzzy logic control on-line experiments at the BR1", Report DR/gvde 34.D046000, 95/99-11, February 1999.

Lectures

D. RUAN, "Softcomputing and applications", Invited lectures at the Institute of Image Processing and Pattern Recognition of Shanghai Jiao Tong University, Shanghai, China, September 1999.

G. VAN DEN EYNDE, D. RUAN, AND D. MARLOYE, "Fuzzy logic control on-line at BR1", lecture at the workshop on Monitoring and Optimisation of Thermal Performance, Halden, Norway, April 1999.