Soft Computing in Fault Detection and Isolation

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Abstract: The main objective of this tutorial is to present the 2005 situation of the state-of-the-art concerning the application of soft computing methods to fault diagnosis and supervision systems. Another objective is to show the unsolved and open problems of modern fault diagnosis and supervision that can be solved either with soft computing methods or hybrid systems based on analytical and soft computing methods. The tutorial is divided into five parts. The first part is devoted to the principles of modern fault diagnosis and outlines the state-of-the-art in this important research area with respect to the so-called analytical techniques. Special attention is paid to problems that cannot effectively be solved with such techniques but can be tackled with the help of soft computing methods. The second part is concerned with the design of fault diagnosis schemes with neural networks. In particular, a number of various solutions to modeling problems for fault diagnosis systems are outlined. A special focus is on robustness to model uncertainty, which is very important in practical applications. Various approaches that can be used for tackling this problem are presented, e.g. an experimental design strategy for reducing parametric robustness of a neural model. Hybrid solutions incorporating analytical methods and neural networks are also presented and suitably analyzed. Finally, fault isolation schemes involving neural-network-based classifiers are presented and discussed. The third part is devoted to fuzzy and neuro-fuzzy schemes for FDI. Similarly as for neural networks, attention is focused on modeling problems for fault diagnosis and supervision. Robustness issues with respect to model uncertainty are analyzed as well. Then hybrid solutions such as fuzzy observers or neuro-fuzzy decoupled observers are presented. Finally, fault isolation schemes involving fuzzy- and neuro-fuzzy-based classifiers are presented and carefully discussed. The fourth part deals with evolutionary algorithm-based approaches to the design of fault diagnosis and supervision systems. In particular, various evolutionary schemes that can be utilized to solve modeling problems for FDI are presented, e.g. a genetic-programming-based identification scheme, experimental design determination with evolutionary search with soft selection. Hybrid solutions such as unknown input observer design with genetic programming or robust multi-objective observer synthesis with genetic algorithms are also presented and carefully discussed. Finally, the last part is devoted to case studies and practical implementations of soft computing and hybrid solutions for FDI and supervision problems. In particular, the task of robust fault detection of an industrial valve actuator is tackled with GMDH (Group Method of Data Handling) neural networks as well as with a perceptron neural network obtained with the experimental design strategy. Another study concerns fault diagnosis of an induction motor with a neuro-fuzzy network and genetic-programming-based observers.

Keywords: fault detection and isolation (FDI), robustness, model uncertainty, neural networks, fuzzy logic, neuro-fuzzy networks, evolutionary algorithms, applications

About the speakers:

Józef Korbicz has been a full-rank professor of automatic control at the University of Zielona Góra, Poland, since 1994. He currently heads the Institute of Control and Computation Engineering (ICCE).

Born in Poland on 19 March 1951, Józef Korbicz received the M.Sc., Ph.D. and D.Sc. (*doctor habilitatis*) degrees in automatic control from the Kiev University of Technology, Ukraine in 1975, 1980 and 1986, respectively. After his return to Poland he was appointed an associate professor of automatic control at the University of Zielona Góra. He obtained his professorial title from the Institute of System Research of the Polish Academy of Sciences, Warsaw, in 1993. In 1991 (5 months) he was with the University of Colorado, U.S.A., as an IREX research fellow, and then in 1994 (2 months) with the Universities of Duisburg and Wuppertal, Germany, as a DAAD research fellow.

In 1991 he founded the *International Journal of Applied Mathematics and Computer Science (AMCS)* and up to now he has been the Editor-in-Chief. Moreover, together with prof. J.M. Kościelny, he founded the *Polish SAFEPROCESS* conferences, the so-called *DPP*. His current research interests include computational intelligence, fault detection and isolation (FDI) and control theory. The primary aim of his research group is to contribute towards the diagnosis of dynamical systems. His research projects in this field has been sponsored by the State Committee for Scientific Research in Poland and since 1997 by the European Commission: INCO-Copernicus on *Integration of quantitative and qualitative fault diagnosis*

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Józef Korbicz has published more than 220 technical papers, 80 of them in international journals. He is a co-author of 8 monographs and text books and a co-editor of 3 books. His last book (co-editor) is entitled *Fault Diagnosis. Models, Artificial Intelligence, Applications*, Springer-Verlag (2004) (with J.M. Kościelny, Z. Kowalczuk and W. Cholewa).
Professor Korbicz is a senior member of IEEE, a member of IFAC TC on SAFEPROCESS, as well as a member of the Automatics and Robotics Committee of the Polish Academy of Sciences in Warsaw. He was a co-chairman of the Programme Committee of the 14th *Polish Control Conference*, *KKA,* in Zielona Góra, 2002.

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