Future Directions of Research in Fault Diagnosis and Intelligent Control of Complex Systems

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Abstract: New approaches for decision making involving fault diagnosis and intelligent control of complex systems have emerged recently. These techniques often use expert systems, fuzzy logic, neural networks etc. but they all suffer from the limitation that a single approach is inadequate for meeting with all the challenges posed by a complex system. A general epistemological framework is, hence, ardently required to be established for this field. The author in his recent research work has attempted to provide such a framework and brought into focus the significant issues of epistemological decision making in complex systems which is emerging as a fertile research area. In this paper, possible directions of future research in this field have been discussed.

Keywords: Fault Diagnosis, Benchmark Process Control System

I. INTRODUCTION

In the pursuit of designing a suitable epistemological decision making framework, some of the basic premises of epistemology as described in various disciplines were reviewed by the author of this paper for providing insight for the development of proposed methodology. The proposed methodology was applied in benchmark fault diagnosis problem of actuator employed in evaporator section of sugar industry for its validation. Then, it was applied on data received from the real industrial environment of sugar industry to showcase its efficacy.

II. DIRECTIONS FOR FUTURE RESEARCH WORK

An effort has been made by the author of this paper to cover all the associated aspects of fault diagnosis in real time industrial systems in general and sugar industry in particular. The results of the research are promising and have yielded useful insights into the mechanism of development of faults and their reflections in the observed parameters. This research has enriched the knowledge of classification of overlapping clusters of faults by means of epistemological processing and visualization, in addition to providing mechanism for fast diagnosis in the case of abruptly encountered malfunctions. This experience has made it possible to outline the general course of future research in this area and suggest some particular areas where immediate action would be beneficial for the industrial world.

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It is hoped that the findings of this research will motivate researchers for designing epistemological frameworks for even greater range of complex problems and for developing a simpler measures for evaluating epistemic utility of the alternative decision-making strategies employed in intelligent control and fault diagnosis applications in complex systems.

Specifically, four potential areas look appealing for future research in this field. Some suggestions for these are as follows:-

Petri nets [1] appear to be a potential tool for epistemological decision making. It is a versatile graphical tool with many applications. It can be used as a visual-communication aid similar to flow charts, block diagrams, and networks. Tokens are used in these nets to simulate the dynamic and concurrent activities of systems. It has a strong mathematical background with facilities to set up state equations, algebraic equations, and other discrete models governing the behavior of systems. Fuzzy Petri Nets have been developed recently for problems with continuous variations of variables and time.

Fuzzy Petri Net is expressed as an 8 tuple:-

$$FPN = (P, T, D, I, O, F, \alpha, \beta)$$

Where:-

$P = \{p1, p2, \ldots pm\}$ is a finite set of places

$T = \{t1, t2, \ldots tn\}$ is a finite set of transitions

$D = \{d1, d2, \ldots dn\}$ is a finite set of propositions

$I: T \rightarrow P\infty$ is the input function, a mapping from transitions to bags of places

$O: T \rightarrow P\infty$ is the input function, a mapping from transitions to bags of places

$F: T \rightarrow [0, 1]$ is an association function, a mapping from transitions to real values between zero and one

$\alpha: P \rightarrow [0, 1]$ is an association function, a mapping from places to real values between zero and one,

$\beta: P \rightarrow D$ is an association function, a bijective mapping from places to propositions.

It is finding numerous applications in sequential control, scheduling, optimization and fault diagnosis of industrial processes, particularly in chemical industries.

It is suggested that further improvement in its efficacy is possible by including perception as one of the variables in the Fuzzy Petri net model. This innovative model would be evaluated by using Computational Theory of Perceptions. It is expected to help in arriving at better decisions in fast manner, making the system useful for intelligent autonomous control of a variety of industrial and real world systems that are characterized as being concurrent, asynchronous, distributed, parallel, nondeterministic, and/or stochastic.

Another promising area of research in this field has been found to be the novel impossibility principle [2], proposed by the pioneering thinker and scientist, L.A. Zadeh. This principle informally states that in an environment of imprecision, uncertainty, incompleteness of information, conflicting goals and partiality of truth, p-validity is not, in general, an achievable objective.

Further, the principles of the extended fuzzy logic, FLe (or FL+), which is a combination of "traditional" provable and precisiated fuzzy logic, FLp, as well as a novel meta-level unprecisiated fuzzy logic, Flu have also been proposed by Zadeh, in the same learned publication. In the FLp the objects of discourse and analysis can be imprecise, uncertain, unreliable, incomplete or partially true, whereas the results of reasoning, deduction and computation are expected to be provably valid. In the Flu, in turn, membership functions and generalized constraints are not specified, and they are a matter of perception rather than measurement.

Since there is a great need to develop logico-linguistic system for complex system fault diagnosis that can operate with imperfect information, impossibility principle and the extended logic "FLe" may prove to be highly effective. It has been pointed out that it also seems possible to apply this principle to the quantitative research.

Study of Convex Bayes theorem based on Levi's epistemic utility and credal convexity [3] suggest that there is scope for formulating simplified mathematical expression for admissible decisions based on epistemological foundations. As the decision making system is committed to seeking additional error free knowledge, there is desire to add the knowledge and at the same time desire to avoid the error. When decision making involves both risk and uncertainty, an option will be admissible if and only if the decision making system is rationally entitled to choose it from the available options given its corpus, state and credal state. Further study in this direction will help in decision making applications involving human-machine interface.

It has been found during the course of research that some faults are intermittent and not permanent in nature. An intermittent fault is a malfunction of a device or system that occurs at various intervals, usually irregular, in a device or system that functions normally at other times. An intermittent fault is caused by several simultaneously occurring contributing factors, some of which may be random. For example, a cause of intermittent fault in a physical system may be a borderline electrical connection in the wiring or a component of a circuit, where two conductors are very close, and actually do or do not establish a connection allowing enough current to flow for correct operation subject to a minor change in temperature, vibration, voltage, etc. If remedial action is not taken in time, these faults many manifest themselves by growing into either incipient or abrupt faults. However, if they are identified in a timely manner, their inherent nature provides enough scope to the plant operators to plan his corrective actions.

It is notable that the more complex the system or mechanism, the greater the likelihood of an intermittent fault. Hence, this category of faults should also be considered in the future works.

III. CONCLUSION

Thus, there is a lot of scope in the area of Decision Making in Complex Systems in general, and Fault Diagnosis and Intelligent Control of Complex Industrial Plants in particular. Hence there is room for not only the extension of the proposed work in the indicated directions, but also for carrying out of innovative research in the newer dimensions as pointed out.

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Brief Biography of Author

Dr Tarun Chopra has obtained B.E.(Electrical Engg) from prestigious M.B.M. Engineering College Jodhpur in 2000 , GATE Scholar, M.E. (Electrical Engg) from B.I.T.Mesra in 2007 & Ph.D.(Electrical Engg) from M.B.M. Engineering College Jodhpur in 2011.

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