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Menoufia University
Faculty of Electronic Engineering
Dept. of Computer Science & Engineering

An Intelligent Hybrid System for Diagnosis and Prediction of the Research Reactor Accidents

A Thesis
Submitted for the partial fulfillment
for the degree of

MASTER OF SCIENCE

By

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2002

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قالوا سبحانك لا علم لنا إلا ما علمتنا

إنك أنت العليم الحكيم

صدق الله العظيم

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Abstract

ABSTRACT

An intelligent hybrid system is presented in this thesis for prediction and diagnosis of accidents of the Multi-Purpose Research Reactor (MPR) of Egypt. Egypt Second Research Reactor, is a multipurpose, open pool type, 22 MW power, light water cooled and moderated with beryllium reflectors. The design concept is based on the requirement of being a reactor of versatile utilization.

To avoid the risk of occurrence of a nuclear accident, the intelligent system should perform the prediction and diagnosis accurately and with high degree of assurance that enables the operator to take the necessary actions. For the reason that each intelligent technique has particular computational properties that make it suitable for particular problems and not for others. For the task of diagnosis we need a system that integrates the ability to learn from knowledge and explanation of decision.

A hybrid intelligent system had been used to satisfy these requirements. The hybrid system consists of neural networks and fuzzy logic. Neural networks are good at recognizing patterns, and gain knowledge by training, but they are not good at explaining how they reach their decisions i.e. black box. On the other hand Fuzzy logic systems, which can reason with imprecise information, they are good at explaining how they can reach their decisions i.e. interpretable, but they can not automatically acquire the rules they use to make these decisions.

The proposed system is composed of two modules, the first module is the Neuro-Fuzzy Classification (NEFCLASS) software that provides primary diagnosis and the second module is a proposed algorithm that performs a fine and accurate diagnosis. NEFCLASS is a linguistic approach for constructing fuzzy systems from data by applying a heuristic data driven learning algorithm

that computes local parameter modifications. There are several other methods that are able to do this but the focus of the NEFCLASS model lies in the interpretability of the developed classifier. The constraints of the learning algorithm allow the user to interactively influence the training process. So the main goal of NEFCLASS is to create a readable classifier that also provides an acceptable accuracy.

The second module, is the proposed algorithm, which provides fine classification. It uses fuzzy sets and rules, which result from NEFCLASS. The idea of the proposed algorithm is based on, refiring the fuzzy sets and rules by the misclassified pattern after shifting its attributes by a small value in the direction of certain variables. These variables are called, dominating variables since the classification results depend on the values of these variables. The proposed algorithm calculates the membership degree of the shifted pattern to each class and decides to which class the pattern is belonging.

The proposed system treats the following cases, unknown classification case, which happens when a pattern lies on the boundary between two classes, and misclassification case, which happens when the pattern membership degree to the target class is less than its membership to the other class. But this requires that the conflicted classes have different dominating variables. When conflicted classes have a common dominating variable, the proposed algorithm can not give decision since, in this case shifting the dominating variables by small values, the total membership degree of the conflicted classes will increase or decrease by the same value and can not give a decision.

The proposed system is trained and tested using reactor data acquired from the nuclear experts in atomic energy authority of Egypt. This data includes 180 patterns, representing 9 classes. The first one is the normal operation class and

other 8 classes represent 8 accidents (e.g. LOFA, LOPS, S_LOCA, M_LOCA, L_LOCA, LOHS, USRI, and UFRI). The reactor training data includes 180 patterns, 20 patterns for each class. The pattern is a vector, which consists of two parts, the first part includes the real values of 15 attributes such as core temperature, core pressure, and core mass flow rate. The second part represents the code of the target class to which the training pattern should belong.

Testing results indicate that the proposed system gives satisfactory results compared to NEFCLASS. By using training patterns, NEFCLASS gives 98.8% diagnosis rate while the proposed system gives 100% diagnosis rate.
However, by using testing patterns, NEFCLASS gives 95.5 % diagnosis rate, while the proposed algorithm gives 98.8%. This means that the proposed algorithm performs a fine and accurate diagnosis.

ABBREVIATIONs

AEA	: Atomic Energy Authority
ARPCS	: Automatic Reactor Power Control Signal
CU	: Control Unit
CWIS	: Chimney Water Injection System
ETRR-2	: Egypt Second Research Reactor
FSS	: First Shutdown System
FU	: Field Unit
I&C	: Instrumentation & Control
LOCA	: Loss of Coolant Accident
LOFA	: Loss of Flow Accident
LOHS	: Loss of Heat Sink
L_LOCA	: Large Loss of Coolant Accident
LOPS	:Loss of Power Supply
M_LOCA	: Medium Loss of Coolant Accident
MPR	: Multi-Purpose Research reactor
NEFCLASS	: Neuro-Fuzzy Classification
RPS	: Reactor Protection System
SBC	: Single Board Computer
SCS	: Supervision Control System
S_LOCA	: Small Loss of Coolant Accident
SSS	: Second Shutdown System
SSIP	: Safety Setting Input Panel
St. St.	: Stainless Steal
SU	: Supervision Unit
TU	: Trip Unit
UFRI	: Uncontrolled Fast Reactivity Insertion
USRI	: Uncontrolled Slow Reactivity Insertion
VPLU	: Voting & Protective Logic Unit