Chapter 5

Hybrid System Approach to Nuclear Plant Monitoring

5.1 Introduction

This chapter is based upon a final report prepared by Charles River Analytics Inc., Cambridge, MA for the U.S. Department of Energy, Germantown, MD under Contract No. DE-FG02-91-ER81178. It describes the results of contract efforts to develop a nuclear plant monitoring system based on a hybrid neural network knowledge base approach. The program was directed by Mr. James M. Mazzu of Charles River Analytics Inc. with Dr. Alper K. Caglayan as the program manager. Mr. Paul G. Gonsalves contributed to the project.

The major objective of nuclear plant monitoring systems is to enable the operator to make correct decisions. The usual difficulties encountered by nuclear plant operators are incorrect assumptions of plant status, insufficient information for fault diagnosis, and prediction of scenarios resulting from various courses of action. To alleviate these difficulties, nonalgorithmic approaches based on neural networks can clearly be of help by replacing and/or augmenting classical analytic measurement validation techniques. Similarly, expert system rule bases can augment the classical hypothesis testing techniques by incorporating operational constraints. Here, we use the complementary strengths of neural networks and knowledge-based expert systems to create a nuclear plant sensor monitoring system that can outperform either method alone.

In this study, we developed a hybrid neural network/knowledge base approach to intelligent sensor monitoring in nuclear power plant applications, developed a hybrid neural network/knowledge base plant monitoring architecture, implemented a prototype plant monitoring system using our neural network/expert system shell NueX on the Macintosh platform, and showed the feasibility of our approach by detecting failures in neuron detectors using in-core neuron flux samples provided by Yankee Atomic.

L. R. Medsker, *Hybrid Neural Network and Expert Systems*

Potential benefits of hybrid nuclear monitoring system are enhanced operator efficiency and performance by providing intelligent operator recommendations, enhanced productivity of the plant operations by detecting off-normal operating states before they drastically affect plant operating performance, increased plant safety by detecting off-normal operating states before they degrade the safety of plant operations, reduced plant maintenance costs by identifying subsystem and component failures before they lead to subsequent failures of related components, and improved operator training in understanding the diagnostic process.

5.1.1 Background

The major objective of nuclear plant monitoring systems is to enable the operator to make correct decisions. The usual difficulties encountered by nuclear plant operators are incorrect assumptions of plant status, insufficient information for fault diagnosis, and prediction of scenarios resulting from various courses of action. The problems of plant mode status determination, information management for fault diagnosis, and prediction of results of controller actions fall into the domain of knowledge-based situation assessment and decision aiding in the domain of artificial intelligence. Here, we use a hybrid neural network and expert system approach to develop an intelligent monitoring system for nuclear plant applications.

Clearly, the starting point of a hybrid approach should be the current state of the art in nuclear monitoring systems. Moreover, the emphasis of an intelligent monitoring system should be the shortcomings of current systems, for instance, hardware redundancy-based measurement validation has been fairly successful. In contrast, analytic redundancy-based measurement validation has not been universally accepted in the industry due mostly to the limitations of analytic plant models. Here, nonalgorithmic approaches based on neural networks can clearly be of help by replacing and/or augmenting analytic measurement validation techniques. Neural networks are used to develop plant models to be used for fault diagnosis instead of the classical parameter identification techniques such as parity space checks, multiple model tests, etc. Similarly, expert system rule bases augment the classical hypothesis testing techniques by incorporating operational constraints.

Recently, artificial neural networks (ANNs) have been applied to a variety of pattern recognition problems regarding fiber optic sensors (Mazzu, Caglayan, Allen, 1992), control reconfiguration (Caglayan, Allen, and Rahnamai, 1989), space vehicle guidance (Caglayan and Allen, 1990), multiple target recognition (Gonsalves and Caglayan, 1992), and remote sensing (Mazzu, Snorrason, and Caglayan, 1992). The advantages of ANN include the ability to classify patterns that vary in an unknown manner, recognize patterns within noise, and recall patterns even if some processing units fail. However, ANNs fall short where