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A COMBINATION OF ARTIFICIAL INTELLIGENCE AND PROCEDURAL LANGUAGE PROGRAMS IN A COMPUTER APPLICATION SYSTEM SUPPORTING NUCLEAR REACTOR OPERATIONS

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A Combination of Artificial Intelligence and Procedural Language Programs In A Computer Application System Supporting Nuclear Reactor Operations

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Abstract

A computer application system is described which provides nuclear reactor power plant operators with an improved decision support system. This system combines traditional computer applications such as graphics display with artificial intelligence methodologies such as reasoning and diagnosis so as to improve plant operability. This paper discusses the issues, and a solution, involved with the system integration of applications developed using traditional and artificial intelligence languages.

Introduction and Summary:

Improving nuclear reactor power plant operability is an ever-present concern for the nuclear industry. The definition of plant operability involves a complex interaction of the ideas of safety and efficiency. In this paper we present our observations concerning the issues involved and the benefits derived from the implementation of a computer application system which combines traditional computer applications with artificial intelligence (AI) methodologies. This system is being installed to support nuclear reactor operations at the Experimental Breeder Reactor II

(EBR-II), located in Idaho and run by Argonne National Laboratory for the Department Of Energy. The implementation problem is that the languages used usually do not provide a mechanism for communication between application components written in procedural languages and AI languages. In the following paragraphs we discuss the application and implementation problems and the associated solutions.

As noted by Lay and Menke[1], currently in the United States, there is very little direct computer control of the reactor in nuclear power plants. The operator controls the reactor through a specified set of complex sequences of switch settings and valve manipulations, that is, a series of component configurations. The knowledge base required of the reactor operator is very extensive. The collection of components can be very large and form an elaborate network with possible many paths. During operation of the plant, the proper interpretation of the sensor readings requires that the operator have a thorough understanding of component relationships and the associated laws of physics and chemistry.

In addition to knowing the physical relationships, the operator must be thoroughly familiar with Technical Secifications (Tech Specs) and administrative regulations. Tech Specs are legal documents which list the conditions and sequence of component configurations which must be observed when operating the reactor. Administrative regulations are plant policy and are determined by management. Within these constraints there is considerable latitude for the operator to control the plant.

Unanticipated plant parameter excursions which approach Tech Spec boundaries are a major cause for the plant to be shut down which in turn results in less-than-optimal plant operation. A measure of plant efficiency is the plant capacity factor (PCF) which is defined by the following formula:

$$PCF = \frac{\text{actual MWHT}}{365 * 24 * \text{authorized power}} * 100\%$$

where MWHT is the number of thermal megawatt-hours generated and the authorized power is given in thermal megawatts.

It was reported in Nuclear News[2] that in the United States the average annual PCF ranged from 51% to 63% from 1976 through 1981. Many of the unexpected shut-downs could be avoided if the operator had currently valid, pertinent presentation of plant parameters, associated "trajectories" of the parameters, and validated analysis of projected changes in component configurations.

Computer applications used in the reactor control room are nearly always limited to data collection, archiving and graphics display. It is not feasible to redesign the control system to provide more direct computer control. Thus, to improve plant operability the alternative is to provide the operator with a support system which will more effectly and directly support the decision processes. The general requirements are that the system provide:

1. flexible, effective operator interaction;
2. validated sensor readings;
3. effective presentation of current plant status (including current component status);
4. effective presentation of reliably projected plant parameters;
5. validated knowledge base;
6. validated analysis and diagnosis of proposed changes in component status, relative not only to the physical requirements but also with respect to the Tech Specs and administrative regulations;
7. performance and responsiveness consistent with plant requirements.

The above specifications combine the more traditional application system requirements with requirements more closely associated with AI. Moreover, the component system can be completely described in a data base along with the rules of interaction so that a reasoning system should be used to provide validated results rather than heuristic methodologies.

A system, the Component Configuration Control System (CCCS)[3], which addresses the concerns and specifications listed above, has been developed and is being installed at EBR-II. The CCCS system has been designed to be generally applicable to other nuclear reactor power plants. Extensive use of computer graphics for both input and output is a major feature of the system. It was decided to use a Prolog implementation, where feasible, for the reasoning portion of the application since a very successful prototype of that portion was developed using the language.

The rapid development of high performance graphics work stations (GWS), interprocess communication within a single central processing unit, and Prolog language processors have made feasible the integration of these components into a single, effective support system for EBR-II. The Sun Microsystems, model SUN-2/160-4 running under the UNIX operating system with Berkley 4.2 extensions, was selected as the GWS. The Prolog system of the Quintus Corporation was selected because of the performance of its compiled code running on the GWS (20k logical inferences/second) and because it has several predicates which can be used to call "C" language functions directly[4]. The features of "interprocess communication" and "calling of 'C'functions" greatly facilitated the process of integrating the diverse components of the system. The "C" language is used as the procedural language for the non-AI portions of the system.

The CCCS quite naturally evolved into a system having four major modules: the users' graphics interaction module (UGI), the functional impact analysis module (FIA), the parameter component state validation module (PCSV), and the alarm prediction and trend analysis module (APTH). In this scheme, the UGI also functions as the executive routine calling on the services of the FIA, the PCSV and the APTH. Usually one would design the system with the UGI as the main program and FIA, PCSV and APTH as subroutines. Since Prolog programs cannot easily be made to act as subprograms it was decided to have FIA, PCSV and APTH be independent "server" processes which communicate with the "client" UGI process using the UNIX "socket" mechanism for interprocess communication[5]. The Prolog programs create and use the sockets by calling "C" functions. Communication between the processes is in the form of strings of ASCII characters.

REFERENCES:

[1] R. K. Lay and J. L. Menke, "Reactor Operations: The Role for Computers", IEEE Transactions on Power Apparatus and Systems, Vol PAS-102, No. 11, November 1983, pg. 3564-70.

[2] E. Michael Blake, "INEL Goes For A Piece Of The New Breeder Action", Nuclear News, Vol. 27, No. 13, October 1984, pg. 50-52.

[3] R. C. Stratton and L. R. Monson, "Component Configuration Control System at EBR-II", Proceedings of Joint ANS/ASME Conference on Design, Construction, and Operation of Nuclear Plants, TANSAO 46 (Suppl. 1) (1984), pg. 46.

[4] Quintus Corporation Prolog product description.

[5] Samuel J. Leffler, Rober S. Fabry and Willeam N. Joy, "A 4.2BSD Interprocess Communication Primer", Digital Equipment Corporation, ULTRIX-32 System Managers, Vol. III, Part 3 pg. 5-28, 1984.