DRIVE REINFORCEMENT NEURAL NETWORKS FOR
REACTOR CONTROL

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DOE Grant No. DEFG03-93-ER-75886

OVERVIEW

The twelve month grant period ending 5/31/94 was originally scheduled to be the second year of a project budgeted for three years. Approximately half way through the year it was learned that grant support for the third year was unlikely to be forthcoming, owing to a lack of continuing funding for the DOE program from which support for this grant was provided.

In view of the loss of the third year funding, the scope of the project goals has been revised. In addition, the rate of expenditures was reduced so as to allow some funds to be carried over by means of a no-cost extension, which has been requested for the period 6/1/94 to 5/31/95. As a result, one of the two graduate students who were supported by this grant has been transferred to other support. A third graduate student's work contributes to the goals of this project without being funded by it. Salary support for the Principal Investigators has been reduced in order to allow the carry over of some funds.

The revision in project scope, caused by the loss of third year funding, no longer allows for the detailed modeling of the EBR-II start-up task that was originally envisaged. We are continuing, however, to model the control of the rapid power ascent of the University of Arizona TRIGA reactor using a model-based controller and using a drive reinforcement neural network. These will be combined during the concluding period of the project into a hierarchical control architecture. In addition, the modelling of a PWR feedwater heater has continued, and an autonomous fault-tolerant software architecture for its control has been proposed.

PUBLISHED RESULTS

During the period of the grant and with partial or total support from its funding, two journal articles have been published, two more have been accepted for publication, and additional articles are in preparation. Papers have been presented at four national or international meetings, and published in conference proceedings. One graduate student supported by the grant has completed an M.S. thesis, and a second will be completed during the summer of 1994. The bibliography of completed publications is attached.

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STUDENT SUPPORT

Three graduate students have been involved in the work supported by this grant. One has completed his M.S. degree with a thesis on neural network associative memories and signal validation systems and is now performing Ph.D. research on a related topic, though supported by other funds. A second student is preparing an M.S. thesis on model-based reactor control during power ascent, after being supported on this grant for one and a half years. A third student, performing Ph.D. research while privately funded, has completed a numerical thermal hydraulics model of a feedwater heater and will be researching the application of hierarchical control systems, including drive reinforcement neural networks.

TASKS

Two specific control tasks were selected to demonstrate the application of drive reinforcement neural networks in reactor control. The tasks were reactor power ascent, and feedwater heater level control.

Reactor Power Ascent

Two separate techniques have been coded and tested for the performance of rapid power ascent in a model reactor based on the University of Arizona TRIGA reactor. Coding has been performed in an object-oriented software structure encapsulated in C++ modules.

A model based inverse kinetics controller, coupled to the reactor model by means of an encapsulated Kalman filter observer, has been tested in performing period based power ascent tasks with demand periods as short as three seconds. Power overshoot problems were observed, as expected, for some transients in which the initial conditions led to a lack of differential control rod worth. Analytical solutions were demonstrated whereby the shortest constant power ascent period, compatible with avoidance of power overshoot, can be specified. Robustness studies were performed which show that the model based controller is sensitive to the reactor model parameters that are assumed, and cannot be reliably used therefore without some supervisory system.

A drive reinforcement neural network was also trained to control the power ascent of the same reactor model. Knowledge of the reactor dynamics was not provided a priori, but was acquired during unsupervised training tasks in which the network observed the correlation between control actions and task performance measured by means of an input cost function. In addition to the specification of the cost function, the selection and partitioning of the sensor system state space proved to be critical design tasks.

Coupling of neural network control with model based control is a remaining task that will be accomplished during the year 6/1/94 to 5/31/95. The neural network will be used in a supervisory role, monitoring the performance, as measured by the deviation from demand, of the model based controller. Drive reinforcement learning will be used to construct corrective control actions when needed, which may arise due to inexact system models or due to incompatible task specifications.

Feedwater Heater Control

A hierarchical fault tolerant architecture has been proposed by the investigators, based on the principle of locally autonomous modules which are capable of self monitoring and reconfiguration in the case of inconsistencies between performance and specifications, which may be caused by departures either of hardware or software from their nominal conditions. The design is intended to fulfill the stringent conditions that the industry demands for safety related functions of digital systems.

The control of water level in individual and banked feedwater heaters has been selected as a test problem for demonstration of the generic system architecture. A numerical software model of a typical PWR feedwater heater has been prepared as a testbed for a hierarchical, reconfigurable control system implementing the principle of autonomous self monitoring. Control strategies that can be tested include simple PI control, as used in existing plant hardware, drive reinforcement neuro-control and other adaptive control systems. Alternative funding sources are being sought to complete the demonstration of these concepts.

Publications Supported by DOE Grant

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