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ATHENA AIDE - AN EXPERT SYSTEM FOR ATHENA CODE INPUT MODEL PREPARATION[a]

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ABSTRACT

An expert system called the ATHENA AIDE that assists in the preparation of input models for the ATHENA thermal-hydraulics code has been developed by researchers at the Idaho National Engineering Laboratory. The ATHENA AIDE uses a menu driven graphics interface and rule-based and object-oriented programming techniques to assist users of the ATHENA code in performing the tasks involved in preparing the card image input files required to run ATHENA calculations. The ATHENA AIDE was developed and currently runs on single-user Xerox artificial intelligence workstations. Experience has shown that the intelligent modeling environment provided by the ATHENA AIDE expert system helps ease the modeling task by relieving the analyst of many mundane, repetitive, and error prone procedures involved in the construction of an input model. This reduces errors in the resulting models, helps promote standardized modeling practices, and allows models to be constructed more quickly than was previously possible.

INTRODUCTION

Preparation of models using a large engineering analysis code is a demanding task in terms of both time and expertise required. The cost of performing analyses is frequently dominated by the engineering labor and time associated with accumulating system data and developing the system models, as opposed to the computer costs to generate the final result. These time-consuming tasks are made easier with experience, and the quality of the model produced is strongly influenced by the expertise of the analyst. The use of expert systems technology is one possible way to reduce the effort and cost associated with computer-aided engineering analysis.

This paper provides a brief description of the ATHENA AIDE (Fink et al. 1987), an expert system developed over the past year and a half at the Idaho National Engineering Laboratory. The ATHENA AIDE assists in

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the preparation of models for the Advanced Thermal Hydraulic Energy Network Analyzer (ATHENA) thermal-hydraulics computer code (Chow et al. 1985).

The AIDE is a prototype developed as part of a research program investigating the application of expert systems technology to the use of large engineering analysis codes. Although developed as a prototype, the ATHENA AIDE is substantially complete and has been used in several working applications.

To provide some context for the description of the AIDE, we first briefly describe the ATHENA code itself. We then describe the capabilities of the ATHENA AIDE, and its usage in developing an ATHENA model.

ATHENA DESCRIPTION

The ATHENA computer code was developed at the Idaho National Engineering Laboratory (INEL) and is a direct descendant of the RELAP5 (Ransom et al. 1985) series of codes. ATHENA is general and can be used in the steady-state and transient simulation of a variety of nuclear and non-nuclear systems involving various working fluids and two-phase mixtures. The code currently can be run on CYBER and CRAY mainframe computers.

ATHENA is based on nonhomogeneous and nonequilibrium models for two-phase flow processes. A six equation model of the process is solved numerically using efficient finite difference methodologies to permit economical calculation of steady-state and transient simulations. An inventory of working fluids is available and includes water, lithium, freon, and helium.

Physical systems are modeled using ATHENA components. These components include generic items such as pipes, pumps, valves, heat structures, heat pipes, and control system components. Special process models are used to describe form losses in hydraulic networks, choked flow, branched flows, noncondensible gas effects, etc. These components and process models are arranged and utilized to form hydraulic and energy networks that represent the geometry and thermodynamic state of the physical system being modeled.

Development of an ATHENA model for a large complex system such as a commercial pressurized water reactor is a time-consuming task, requiring as much as a man-year of effort. The input file for such a model may contain upwards of 5000 lines of input records.

ATHENA AIDE DESCRIPTION

The ATHENA AIDE is an expert system that assists in the construction and manipulation of models for the ATHENA code. The system currently operates on Xerox 1100 series workstations. An object-oriented programming approach using LOOPS and Interlisp-D (Stefik and Bobrow 1986, Xerox 1985) is used for representation of the knowledge and information required to construct an ATHENA model. The ATHENA AIDE is user friendly and utilizes a menu driven, graphics interface with the user. Figure 1 illustrates a typical screen display from the ATHENA AIDE.

The goals of the ATHENA AIDE system are twofold: first, to provide an intelligent environment, capable of handling most of the mundane data management tasks for the analyst (to reduce the development time for the model); and second, to provide a platform for expert system assistance to the analyst (in the hope of improving the quality of the model).

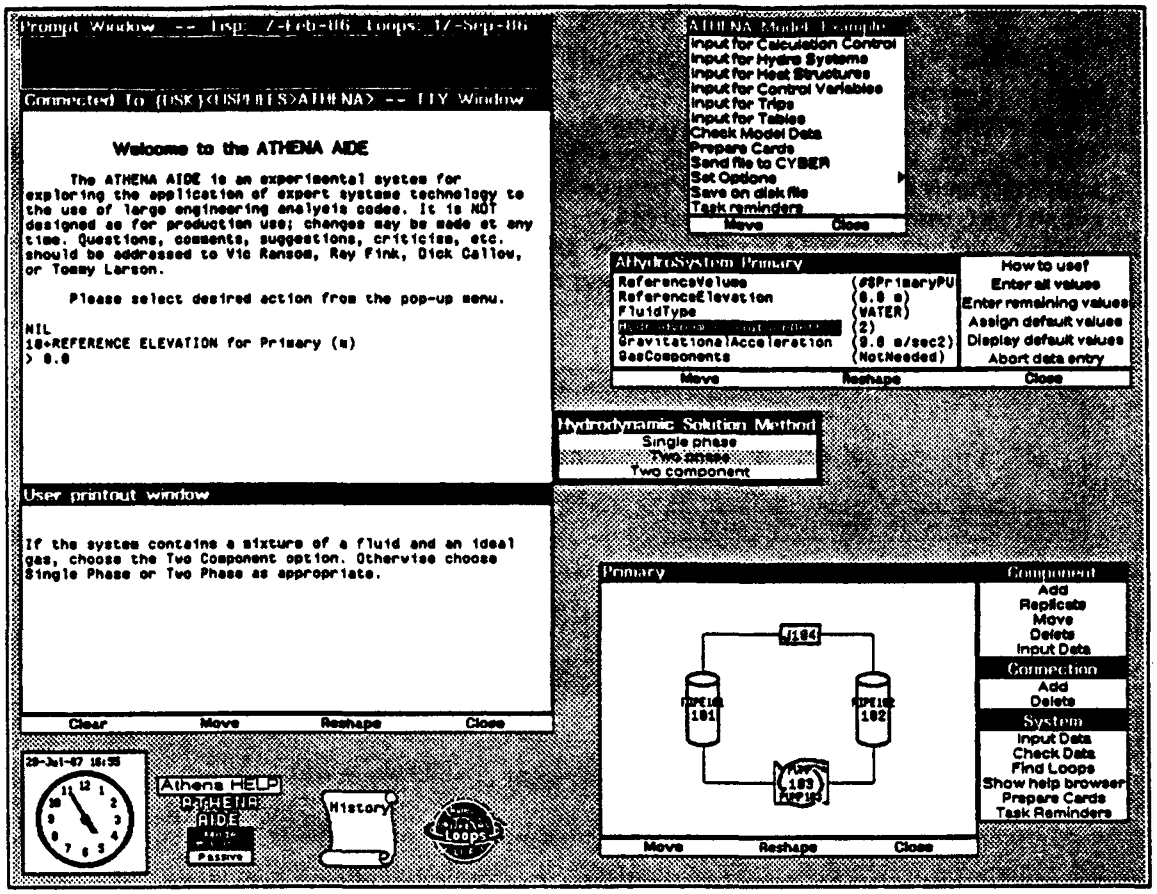

Fig. 1. ATHENA AIDE screen display.

An ATHENA model of the physical system of interest is constructed using the graphical interface features of the ATHENA AIDE. The analyst performs the initial abstraction of the physical system by arranging and connecting iconic representations of ATHENA components such as pipes, pumps, valves, etc. on the graphical interface. Figure 2 illustrates a typical hydrodynamic system layout on the ATHENA AIDE screen. If the analyst wishes to work with an existing model (developed outside of the AIDE), the ATHENA input file for the model can be read into the AIDE.

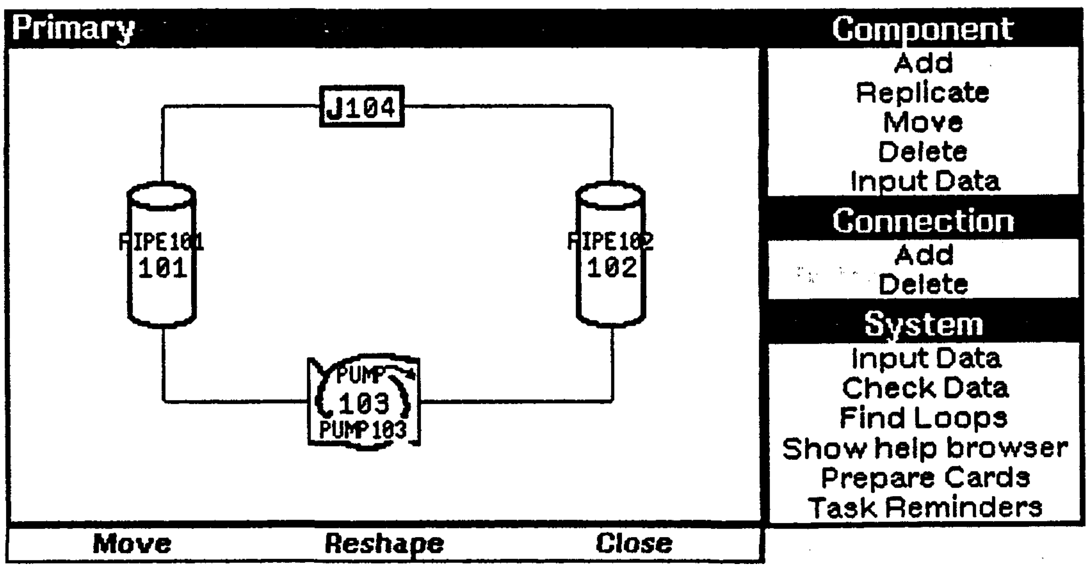

Fig. 2. Sample hydrodynamic system layout.

Rule-based consultations based on heuristic knowledge for specific physical systems are available to assist in the component selection and to prevent unacceptable modeling practices; Figure 3 shows the screen display for one such advisory system. These expert system advisors are invoked in response to help requests from the analyst, or they may be consulted on a stand-alone basis. If appropriate, the result from the expert system consultation may be incorporated directly into the model under consideration (subject to approval by the user).

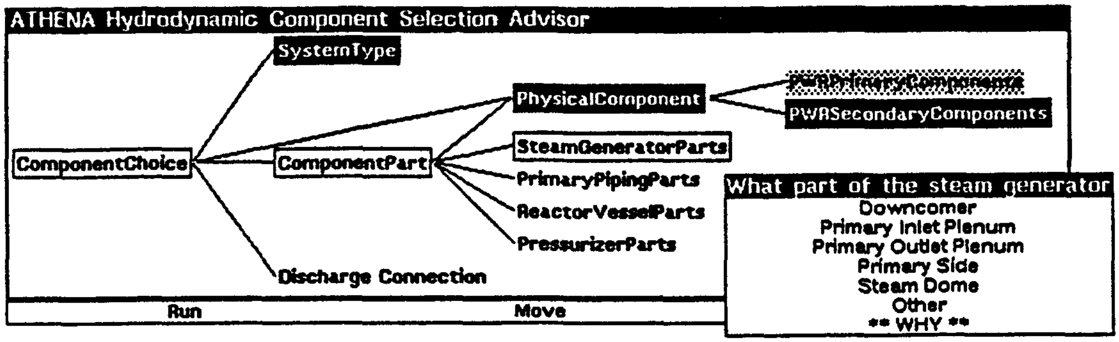

Fig. 3. Expert system advisor for component selection.

Parameter input for each component is handled through an edit window as shown in Figure 4. Each component has knowledge of what parameters are required, what default values may be suitable, and what requirements apply to any parameter value. The expert system prompts the user for required geometric and thermodynamic state information for each selected component. Error checking is provided to prohibit incorrect input and help minimize modeling errors. Help functions can be activated at nearly any stage of the model construction process to provide detailed information on input requirements. Engineering units conversions are handled automatically so that the analyst can work in any system of units desired and change units at will during the model construction process.

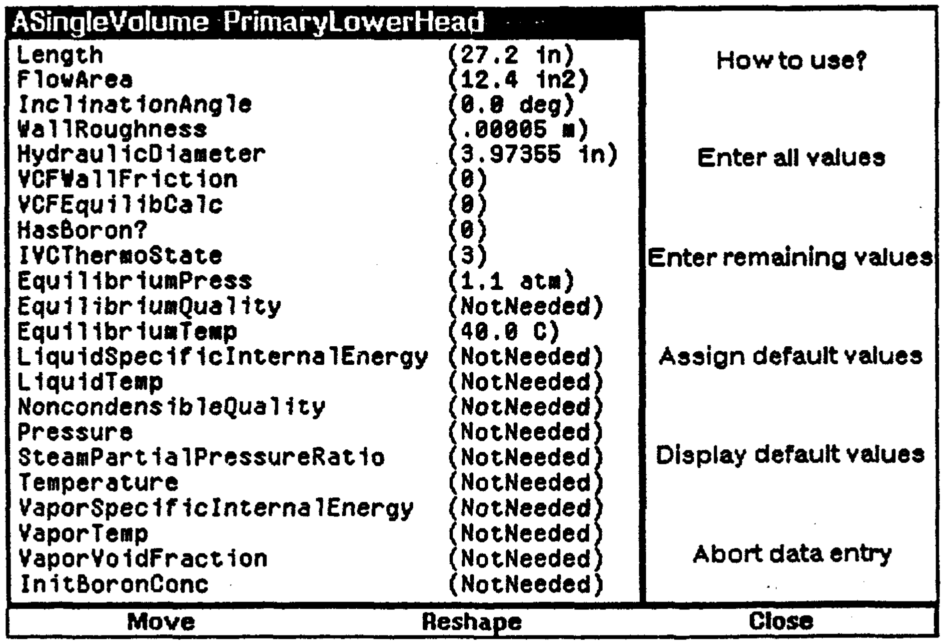

Figure 4. Sample input edit window.

The expert system automatically maintains a list of tasks remaining in the construction process to remove such burden from the analyst. Each component in the model has knowledge about its current state of completion, and what sequence of additional tasks is necessary to complete its specification. This task list is used to provide an agenda for the analyst, allowing the analyst to resume threads of model development that were interrupted by delays to obtain additional data, meetings, weekends, or other impediments to engineering progress.

An audit capability in the ATHENA AIDE maintains the creation date and dates on which components in a model are altered. For historical documentation or quality control purposes, the analyst may also enter comments regarding decisions and assumptions made during the modeling process into the audit record. This audit trail is maintained as an integral part of the model, and can be sorted by date or by component as required.

The ATHENA AIDE has two modes of operation: automatic and passive. In the automatic mode the system will interact closely with the user and lead the user through the model construction process. In the passive mode, the system interacts in a less obvious, nonintrusive manner; the user retains control over choice of "what to do next." The passive mode is intended for the more experienced analyst, who is more likely to have a definite opinion on what order should be used to develop parts of the model. The mode may be changed at any time via a menu selection.

After development of the model is completed, the ATHENA card image input file is automatically generated in the required format. This file can then be stored on hard disk, floppy disk, or routed via standard file transfer packages to a mainframe computer.

BENEFITS OF THE ATHENA AIDE

Preparation of ATHENA models for complex physical systems is a difficult and time consuming task. Efficient, successful use of the code is an art for which guidelines addressing use of the ATHENA code and proper model construction practices have been developed from practical applications experience with the code. The ATHENA AIDE utilizes this heuristic knowledge to promote adherence to standard modeling practices.

The extensive error checking, units conversions, and help functions all assist in substantially reducing the time required to develop a correct and complete model. Although the AIDE has not been been placed in production use, it has been used by novice ATHENA analysts in several small-to-medium sized modeling applications. In these applications, model construction time has been reduced by fifty to eighty percent of that typically required.

LESSONS LEARNED

Development of the ATHENA AIDE prototype has led to several conclusions regarding the use of expert systems for engineering analysis computer codes. Perhaps most important is the need for an intelligent modeling environment. A stand-alone consultant expert system can only be used in very limited contexts, and does not address the enormous data management needs of the analyst. The intelligent environment can substantially ease the analyst's data management problems, as well as provide the necessary expert system support.

Much of the value in an intelligent modeling environment is obtained from relatively mundane support capabilities. Engineering units conversion, help messages, and immediate error checking are examples of these kinds of necessary capabilities.

The characteristics of the user interface affects the users' perceptions of a system. In the ATHENA AIDE, it was necessary to use graphical symbols for the hydrodynamic system that were very similar to the diagrams typically used for analysis reports, in order to gain acceptance of the system. Analysts who were unaccustomed to a large bandwidth interface (multiple windowing, pop-up menus, mouse-sensitive screen regions, etc.) needed more time adjusting to the system than we had originally expected. To solve this problem, we found it necessary to "tone down" the interface: all text input constrained to one window, all pop-up menus occurring at the same screen location (and strongly highlighted), and explicit feedback on system status (e.g., working, waiting for input, or idle). Although these efforts did little to improve the capabilities of the system, they strongly influenced the acceptance of the system.

Finally, the choice of delivery system is important. Although the Xerox AI workstation was an excellent platform for development, most analysts expressed a preference for having the system on more widely available computers such as PC's or the time-shared mainframes. The analysts preferred having such a system in their office (rather than down the hall or across the building) and were unlikely to purchase a special purpose workstation solely for modeling work.

CONCLUSIONS

The ATHENA AIDE modeling environment provides the capability for more rapid construction of complex models, promotes the use of standard modeling practices in these models, helps to reduce errors in the input, and provides a convenient historical documentation of model development and evolution. Much of the utility of the system derives from support for the analyst's data management problems, rather than the traditional expert system advisory capabilities. The quality of the user interface was found to have a substantial impact on the perceived utility of the system.

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