1 of 1

ANL/XFD/CP--79549
CONF 931023--5

A RULE-BASED EXPERT SYSTEM FOR GENERATING CONTROL DISPLAYS AT THE ADVANCED PHOTON SOURCE*

Karen J. Coulter
Experimental Facilities Division, Argonne National Laboratory

RECEIVED
NOV 08 1993
OSTI

ABSTRACT

The integration of a rule-based expert system for generating screen displays for controlling and monitoring instrumentation under the Experimental Physics and Industrial Control System (EPICS) is presented. The expert system is implemented using CLIPS, an expert system shell from the Software Technology Branch at Lyndon B. Johnson Space Center. The user selects the hardware input and output to be displayed and the expert system constructs a graphical control screen appropriate for the data. Such a system provides a method for implementing a common look and feel for displays created by several different users and reduces the amount of time required to create displays for new hardware configurations. Users are able to modify the displays as needed using the EPICS display editor tool.

Introduction

The Experimental Physics and Industrial Control System (EPICS) consists of a set of software components and tools with which application developers can create a control system. It is being used for the control system at the Advanced Photon Source at Argonne National Laboratory. EPICS allows the developer/user to configure a database which interacts with a particular set of instrumentation, and to create a graphical display to communicate with this database. However, the EPICS tools which allow the user to perform both of these functions are entirely independent; the user is responsible for transferring the information from the database to the display in an appropriate fashion. The user is also responsible for determining how best to represent the instrumentation I/O in the graphical display. This work describes the development of an expert system to assist in the creation of the graphical display, both in choosing appropriate display components and in transferring information from one tool to another.

The basic components of EPICS are: 1) an Input/Output Controller (IOC), a VME/VXI-based chassis containing a Motorola 680x0 processor board and various I/O modules and VME modules, which interface to the hardware to be controlled; 2) the operator interface (OPI), a UNIX-based workstation which can run various EPICS tools; and 3) a local area network (LAN) which allows the OPIs and IOCs to communicate. The heart of an IOC is a memory resident run-time database and the various structures which represent the hardware configuration for the particular set of instrumentation controlled by the IOC. The database is generated on a workstation by an application developer and downloaded to the IOC at IOC boot time. The OPI, operator interface, can run many EPICS tools, among them are the Database Configuration Tool (DCT) for creating IOC databases, and the Motif Editor/Display Manager (MEDM) for creating operator displays. MEDM displays are X Window-based graphic displays which are

* Supported by the US Department of Energy, BES-Materials Sciences, under contract W-31-109-ENG 38.

dynamically linked at run-time to the IOC database, providing an I/O interface between the operator screen and the hardware. Displays can be very simple or very complex, depending on the database and the degree of operator interaction required. MEDM display objects include monitors and plots, for instrument output; controllers, for operator input; and statics (text, lines and polygons) which usually do not change while the database is running, but provide useful information to the operator (labels of displayed fields, illustrations of the hardware arrangement).

DCT and MEDM are separate EPICS tools. An application developer must first use DCT to generate the database, and then use MEDM to generate the display. In DCT, every database record is given a record name; the name is then used by MEDM (and other tools) to update values during run-time. MEDM has a sophisticated Motif and X-based operator interface for defining displays and provides over 20 different object types for use in displays, but it has no interface to the information already stored in the IOC database. Therefore, the user must remember record names and other information entered into the database tool, and must re-enter them in the MEDM tool. The process can be slow and painful even for experienced application developers.

A rule-based expert system for generating MEDM displays has been developed using the CLIPS expert system shell from the Software Technology Branch at Lyndon B. Johnson Space Center. The expert system interacts with both the IOC database definitions and the MEDM object definitions. The purpose of the expert system is to access the database definition, and advise a novice user of EPICS on the most appropriate display object to use for specific database entries selected by the user. It then automatically generates an MEDM display suitable for IOC database startup and debugging. As users become more familiar with MEDM, they can use it to modify the display as needed. One benefit of such an expert system is that it can provide a framework for a common look and feel across displays created by all users. It also reduces the amount of time required to create initial displays for new databases, even for users who are proficient with the MEDM, since database information is retrieved by the expert system, and does not have to be re-entered by the user.

Implementation

An EPICS IOC database fully describes the hardware configuration and the device driver routines to be used to control a particular set of hardware devices. The IOC database structures are fully described in the EPICS documentation [Ref 1 and 2]. Each individual hardware device or hardware function is represented by one *record* in the database. Each record type has a fixed set of *fields* which contain information such as physical address, data type, and range of allowed values, for that particular hardware device or function. Some fields are common to all record types, and others are specific to particular record types. One of the field types common to all records is the VAL field which is the primary value of interest for that record, i.e. device. Fields other than the VAL field may also be of interest to an operator and therefore need to be displayed. A record can be an input record, which reads data from a device, an output record, which writes a value to a device, or a "soft" record, which simply means that the record is providing storage for data which may be retrieved when needed by other records.

When a user invokes the expert system, the records in the IOC database are read, and any information required by the expert system is stored. The user is asked for which records a display object is desired. The user decides whether or not to display the VAL field. If the user wishes to display additional fields, a selection of displayable fields from which to choose is given to the user. The user may be asked a few questions such as the expected behavior of the data in the field, or whether a certain class of object is preferred

(e.g.: text vs. graphical). For each field to be displayed, the expert system determines which object (sometimes multiple objects) is most appropriate and adds the object to the display description file. When the user has selected all fields to be displayed, the expert system exits, and the user then runs MEDM, which reads the display description file and generates the graphical display.

Knowledge Representation

The EPICS software itself imposes some rules about displaying database fields. Many field types are not modifiable or even accessible while the database is executing. Reference [2] documents these rules and also gives a "level of interest" as determined by the EPICS authors. This level of interest provides a guideline for choosing which fields will be useful to display, and which can be operator-controlled vs. which can only be monitored. Fields which are intended to be under operator control require a controller object, or the operator will have no way to send data to the database field. Many fields can be updated only by hardware or by other database records and those also require a monitor rather than a controller. Placing a controller object on an unmodifiable field is illegal. Since MEDM is not integrated with the IOC database definitions, it is up to the application developer to follow these guidelines. They are not enforced when creating a display, but the developer will have a rude awakening when trying to activate a display with "illegal" object assignments.

Experienced operators and applications developers also have rules and preferences for displaying certain types of information. Often these rules are not absolute, rather they are applied "most of the time," with certain conditions having precedence over others. These rules are undocumented and must be derived through interviews and observations. Often an operator doesn't realize that a rule is actually being applied until it is pointed out by someone else.

In this expert system application, the knowledge base is stored in two ways: through rules and simple facts. The rules are of the form "IF x THEN y (ELSE z)." The antecedent, x, is often a complex list of conditions. A particular rule may generate a direct solution, or may generate intermediate data which is then used to fire other rules. Facts are simple assignments of solutions to individual conditions. For the VAL field, which occurs in all record types and must therefore be more flexible, the knowledge is stored in a series of rules which categorize the VAL by whether or not it is input/output/soft, continuous/discrete, coarse/exact values, etc. Some of this information can be determined from the IOC database, and some must be supplied by the user. For many fields other than the VAL field (and in some cases, also the VAL field), the type and range of the data for that field are fixed by the EPICS record definition and/or operator expectations, so the knowledge of how to display these fields can be stored as simple facts.

Both the series of rules, and the simple facts used for determining which object to generate for a specific field type were composed after carefully reviewing the EPICS documentation and interviewing EPICS application developers. For the record types that currently exist in EPICS, many of the field types demand a certain display object in order for the data to be unambiguous for the operator. However, as the number of record and field types grows and more display objects become available, it is likely that many of the simple facts and some of the rules currently used, will have to be reconfigured into a series of more complicated rules derived from the experiences of the application developers and operators. Operators will be interacting with the application developers and providing feedback on the actual use of the displays, which also should be incorporated into the knowledge base.

Discussion

This particular application lends itself well to the implementation of an expert system. The learning curve for building a graphical display from scratch can be fairly long, however modifying an existing display is quite a bit simpler. Much of the database record information must be re-entered when creating a display, and it is much more efficient and reliable to have an automated transfer of information, rather than rely on the user to remember or look up the data. Therefore this is a very useful tool to have for those generating EPICS displays, both experts and novices. The rules and facts used to encode the knowledge for building a graphical display are currently fairly straightforward, although it would not be simple to code them in a linear fashion, such as in a C program. The syntax of CLIPS rules allow one to reasonably translate operator/developer rules into executable code. By the same token, the code rules are easily read and verified by non-programmers of CLIPS. The knowledge base is stored as rules and facts which get executed by the expert system shell. So the knowledge base is stored in one location rather than spread throughout pages of supporting code. Maintenance, verification and updating of the knowledge base would be far more complicated if it were implemented in a 'standard' programming language.

By far, the most time-consuming aspect of this project was integrating the CLIPS code with the EPICS database and display manager tools. A smooth integration with the database tools reduces the number of open-ended questions asked of the user (where the user is not presented with a list of allowed responses). Error-checking can be done at data entry instead of at run-time. It also allows for expansion and revision of the knowledge base and/or database structure without completely reworking the interface between tools. This area of the project will probably continue under development, as the current interface should be made more robust and more generic. Generating the graphics description file also introduced some unanticipated behaviors in the early stages of the project. This segment of the code also should include more levels of abstraction, so that new graphics objects and object properties can be added in a simpler fashion. The fact that this aspect of the project was very time-consuming is not to say that CLIPS was not a good framework for building the expert system. It was, in fact, an excellent choice which provided a flexible interface, allowing C routines to call CLIPS functions, and likewise, CLIPS functions could execute C routines.

In addition to simplifying the creation of EPICS graphic displays for controlling and monitoring instrumentation, this expert system offers a framework for imposing (and modifying when necessary) standards for color, sizing, font types, layouts and unique identifiers, across all developers creating displays. For a large project such as the Advanced Photon Source, where many developers will be creating screens, this interface consistency can be extremely beneficial for simplifying the job of the control room operators, who, at any given time, must deal with many screens created by many different developers.

As more developers become MEDM experts and more sophisticated displays are created, the expert system will have to be periodically evaluated to ensure that the display objects are chosen appropriately. As construction at the Advanced Photon Source continues, more complex hardware systems will be supported under EPICS, and information on how best to display the associated database records will have to be added to the expert system knowledge base. The possibility exists for expanding the expert system to make decisions regarding object attributes, such as size, color and placement on the screen. Another consideration for the future is the possibility of creating a tool to analyze the databases and associated displays (after much use and final modifications).

This tool could then use the results of the analysis to evaluate or even modify the knowledge base used for generating displays.

References

1. Experimental Physics and Industrial Control System (EPICS) Source/Release Control, Zieman, R., and Kraimer, M., Argonne National Laboratory, Draft - October 1992.
2. Experimental Physics and Industrial Control System (EPICS) Input Output Controller Record Reference Manual, Anderson, Janet B. and Kraimer, Martin R. , Draft - October 1992, Argonne National Laboratory.
3. Mr. Ned Arnold, Applications Engineer, Controls Group/Accelerator Systems Division, Argonne National Laboratory, personal communications.
4. Mr. Mark Anderson, Systems Engineer (author: Motif EPICS Display Manager), Controls Group/Accelerator Systems Division, Argonne National Laboratory, personal communications.
5. CLIPS Reference Manual Vol. I Basic Programming Guide, Vol. II Advanced Programming Guide, Vol. III Utilities and Interfaces Guide, CLIPS Version 5.1, Software Technology Branch, Lyndon B. Johnson Space Center, September 10, 1991.
6. CLIPS User's Guide Vol I. Rules, Giarratano, Joseph C., CLIPS Version 5.1, Software Technology Branch, Lyndon B. Johnson Space Center, September 10, 1991.
7. Expert Systems, Principles and Programming, Giarratano, Joseph C., and Riley, Gary, PWS-Kent Publishing Co., 1989.
8. Knowledge Acquisition: Principles and Guidelines, McGraw, Karen, and Harbison-Briggs, Karan, Prentice Hall, 1989.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**DATE
FILMED**

1 / 21 / 94

END