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PROGRESS IN COMPUTER-ASSISTED DIAGNOSIS AND CONTROL OF NEUTRAL BEAM LINES

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ABSTRACT

This paper discusses the principles that have guided the development of a computerized diagnostic and control system for both the Neutral Beam Systems Test Facility at Lawrence Berkeley Laboratory and the Doublet III neutral beams at the General Atomic Company. The emphasis is not on the particular details of the implementation, but on general considerations which have influenced the design criteria for the system. Foremost among these are the requirements of an appropriate human interface to the system, and effective use of a relational data base. Examples are used to illustrate how these principles are carried out in practice. A systems view of diagnostic programs is suggested in the light of our experience.

1. INTRODUCTION

Prior to the start of the Neutral Beam Test Facility at LBL in the mid-1970's, the Real Time Systems Group had been engaged in implementing computer control and diagnostic systems for several of the particle accelerators at the Laboratory. From experience gained there, two principles emerged which have helped shape the present neutral beam computer system. They are:

1. The need for an appropriate human interface to the computer system. It was recognized that the operators of particle beam accelerators have to deal with large amounts of complex data in real time and frequently need to access several different kinds of data quickly and easily. Moreover, they are generally well acquainted with the more conventional forms of data displays, notably oscilloscope traces, and have neither the time nor the inclination to sit at a computer terminal and learn even a very high level set of protocols while they are busy doing their primary tasks. Thus, one of the

prime objectives of our group was the development of a graphics system that was both natural to use and "friendly". This system is discussed further in Section 2.

2. The importance of a relational data base as an integral part of the system design. Much has been written about data bases, their theory and implementation. Nevertheless, their use is not as common in a scientific environment as elsewhere. We discuss the advantages of a data base system in the context of neutral beams in Section 3.

In Section 4 we suggest that the traditional view of diagnostic programs as a collection of clever algorithms is not sufficient, in view of the need for an integrated systems approach.

2. THE OPERATOR INTERFACE

In an effort to create a simple and convenient communication medium between the human operator of the beamline and the computer, LBL designers are using three large CRT screens (one color, two black/white), with one screen equipped with a Mylar touch panel [1, 2]. The touch panel, combined with logical (software) buttons, constitutes an effective way for the operator to generate an external interrupt to the computer. Its most obvious use is in selecting displays from a "menu" of choices, but there are more interesting uses, especially when the touch panel is combined with input knobs via a microcomputer, as in the following example.

2.1 The Timing System -- An Example of the Use of the Touch Panel

Figure 1 shows one of the seven timing displays that can be called up on the touch panel by pressing a menu button. Once the display appears, any of the timing signals named on it can be referenced by first pressing the button surrounding the name (e.g., "Gas" in Fig. 1). Two knobs then

control the leading and trailing edges of the pulse. As the knobs are turned, the pulse will move left or right and widen or narrow accordingly. At the same time, the appropriate numbers will appear in the box immediately to the left of the pulse name. When the operator has set the timing pulses to his satisfaction, "Change Timers" is pressed and the modifications are entered into the computer's data base. As may be seen in the figure, the displays are also equipped with a "zoom" feature (Expand/Shrink Display). Misplaced pulses (e.g., arc before filament) are avoided by software interlocks that automatically move related pulses as needed or prohibit the adjustment of others. Virtually all timing signals at NBSTF are now under this type of computer control.

2.2 Deleting Sensors -- Another Touch Panel Example

Another interesting use of the touch panel/logical button interface is the ability to delete temperature sensors during calorimetry analyses. Fig. 2 shows a sensor control display, a Doublet III calorimeter. By touching any of the sensor buttons and then updating the status control, the temperature measured at that position is removed from (or brought into) consideration in data fitting and smoothed when plotting isothermal contours. Since thermal sensing devices may fail for a variety of reasons, this ability to "remove" them immediately can be and is very useful.

The buttons acknowledge a hit by brightening their borders and carry whatever legend the programmer desires to place there. A set of Fortran-callable subroutines that interface with the graphics system is available for manipulating the buttons. All changes to display layouts are therefore done in a high-level language.

3. THE IMPORTANCE OF THE DATA BASE

This concept has been discussed at length in [3]. For our purposes, two particular characteristics of the data base are worth noting:

1. It contains a description of all the physical characteristics of the neutral beam lines needed for computer analysis and display.

2. It permits a "decoupling" of the analysis and display programs from the details of the instrumentation hardware and data acquisition tasks.

There are three important advantages to be gained from these features:

First, the data base helps to create a natural modularization of the system, since it is possible to think of single purpose tasks which need not carry along explicit assumptions about the data inputs or beamline devices with which they are dealing.

Second, it provides a central store for all data, permanent and transient (shot-to-shot). This improves debugging and maintenance efficiency, since changes in the physical description of the system (which are frequent) occur in only one place.

Third, several different beam lines, perhaps with quite different physical characteristics, can be described in the data base, and the individual programs need have no "wired-in" knowledge of their differences, or of which one is currently active.

An example seems appropriate here to illustrate these three points:

3.1 The Data Base In Use: Many Devices on Many Beam Lines

As one of our diagnostics, there is a task that fits the temperature data, read from any of several calorimeters, to a theoretical model of temperature distribution [4], and another task that displays the results of that analysis. Let us look more closely at the input data needed by the display task. It requires the size and shape of the calorimeter and the

relative positions of the thermocouples. It needs the parameters obtained from the data fitting process, the maximum temperature, and a host of other data items that change from shot to shot (Fig. 3 shows this display). It also needs some text that does not change from shot to shot in order to make the information meaningful. It does not need to know, however, what all this information is, only where to access it (just the opposite of the human who reads it).

Our system uses a message service. When a task is activated, it receives a start-up message which contains the beam line number, source number and a two-character device code. If, for example, the system is the present NBSTF beamline at LBL, the start-up message will contain the ASCII string 0002BD, which translates to beamline 0, source 2, beamline calorimeter. This provides the only specific information which the task will need in order to form a unique data base name. That name will, in turn, refer the task to pointers and files that contain the specific instances of the general data types described above. Moreover, much of this data is shared by various tasks. For instance, the locations of the thermocouples on a variety of instrumented devices are stored in the data base and used by a number of programs, each time accessed by the technique just described. Thus, to continue the examples, the display task will display the acquired data in positions which appear on the screen in the same relative positions as the thermocouples on the device. Figures 4 and 5 show two such displays, for the NBSTF neutralizer and ion dump calorimeter, respectively. Exactly the same task is used for all such displays (presently more than twenty) with the identifying information contained in the message received from the message service.

Since similar message services are generally available in real time operating systems now, these techniques can be implemented in any such

system with a relational data base.

These ideas can be carried a step further. From the computer's point of view, the positions on the CRT screens and the colors of the pictures and text constitute part of the description of the display. Thus, these too are included in the data base and a set of simple Fortran-callable subroutines are used first to get this information and then automatically display it. The considerable advantage of this approach is that the same information can be displayed in different arrangements on the screen, as a function of the geometry of the associated device (see Figs. 4 and 5), again without explicit assumptions built into the display program.

4. DIAGNOSTICS: A CHANGE IN VIEWPOINT

A wide variety of diagnostics is presently available on our system, with more under development. Included are:

1. A full range of calorimetry tasks (temperature displays, isothermal contouring, temperature data fitting and analysis), all of which respond to operator control of the sensor status buttons, as described in Section 3.2.
2. Power supply waveform displays.
3. Plasma probe waveform displays and profiles.
4. Photodiode analysis of the beam.
5. Perveance line and tuning curve displays for source conditioning.

This list is not exhaustive. Some of these diagnostics are used only occasionally, while others, such as the calorimetry analyses and the plasma probe profile, relieve the operators and physicists of an immense amount of data gathering and reduction and speed up beamline operations immeasurably.

Traditionally, in scientific laboratories, the emphasis on diagnostics has been almost totally algorithmic. How to derive the information from raw data naturally takes a great deal of thought and effort. However, with an emphasis on graphical output and a data driven system the presentation

of that information and the integration of the diagnostic tool into the system play an equally important role. No one should think that this change in viewpoint constitutes a denigration of the importance of first rate computational algorithms. They require special knowledge and often are an art in themselves. However, we recognize that in a well-designed real time system, which must provide flexibility, ease of maintenance and comprehension to the operator, these other considerations must also enter. Thus, when a diagnostic is designed, thought must be given to the system tools which will be useful to the task.

4.1 The Plasma Probe Profile: An Example of an Integrated Diagnostic

The plasma probe profile display relieves the operator of a tedious chore, while providing important information on the plasma density in the source's arc chamber.

The waveforms of eight Langmuir probes, located in the chamber, are read, digitized and acquired by the computer. Ideally, all probes should have the same average value and significant deviations from a central value are carefully monitored.

The display is seen in Fig. 6, with idealized data. A line graph of the average values is drawn (the vertical lines are a measure of the variation in each waveform). The average values themselves appear in a table at the right and the ratio of largest to smallest is shown. (This is the key value; a ratio greater than about 1.25 is cause for concern.)

A typical version of such a diagnostic tool might first get the probe waveforms, average them in a subroutine and then display the results, with a good deal of in-line assumptions and decision making. While the process is conceptually and computationally simple, the job can become difficult because of the large number of input variables that have to be specified; e.g., the number of digitized samples, the sampling rate, the gains and

offsets for conversion to engineering units, the waveforms themselves, the locations on the screen and scaling constants for displays, etc. Many of these are subject to frequent change.

In our system, waveform averaging is accomplished by a separate task which, given a list of the waveform names, does the averaging and computation of the variation, taking waveform interrupts into account. Needless to add, this task finds its inputs by forming a unique database name, as described in Section 3. For displaying the information, the probe profile task uses our standard graphical routines which allow the formats and screen location of the information to be specified in a database file. thus, the integrated display task reduces to identification of the inputs, design of the data structures and graphical format, effective use of system aids, and, in this case, a relatively small amount of algorithmic processing.

5. SUMMARY

We have tried to show, in this brief exposition, that a systems approach to a diagnostic and control design of the type required for neutral beam operations is desirable for several reasons. It leads to a unified view of the various diagnostic programs, encourages modularity and helps programs to avoid the dangers of wired-in assumptions. In addition, we believe the attention given to the human interface is worthwhile from the point of view of operator acceptance and comprehension.

This approach is not without its price. Writing programs will sometimes require more work to assimilate the program into the system than would otherwise be the case, and a certain amount of discipline is necessary to guarantee that standard interfaces and programming conventions are maintained. But our experience suggests that this is a price worth paying.

CBB 808-9352
NBSTF Control Room

XBB 808-9375

Figure 1.

XBB 808-9618

Figure 2.

Figure 3. CBB 808-9356

Figure 4. CBB 808-9358

Figure 5. CBB 808-9370

Figure 6. CBB 808-9354

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