APPLICATION OF HIGH LEVEL PROGRAMS IN A CONTROLS ENVIRONMENT

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Summary

Highly interactive display utilities, operating on a VAX/VMS computer system, have been usefully interfaced to the controls environment of the TRIUMF cyclotron. Machine data is acquired by a VAX-CAMAC interface, and is passed to these utilities in an efficient manner by memory mapping to global sections for on-line manipulation. The data can also be readily analyzed off-line by operators with the user-friendly command driven utilities OPDATA and PLOTDATA which permit the user to obtain graphics output on a variety of terminal and hardcopy devices using device independent metafiles. Sample applications show the usefulness of these utilities for a wide range of tasks, such as real-time simulation of trim-coil tuning on the beam phase history, and semi-on-line analysis of radial probe data.

Introduction

The TRIUMF control system was developed more than 10 years ago, and although based on the latest equipment available at the time, it is now somewhat obsolete in the sense that operators cannot readily display machine parameters or derived parameters in a graphics environment. Although it is planned to upgrade the control system to allow this, we have, in the meantime developed some tools on a VAX having access to a CAMAC interface.

Display Hardware

A CIT-467 colour graphics terminal which is Tektronix 4010 compatible with 572*480 pixels, 8 colours, and with a separately scrollable, but overlaying VT100 text plane of 80/132 columns by 24 lines, is used as the primary display media. Although much more expensive colour graphics workstations (based on microVax II hardware) are currently being interfaced to the controls environment, they will take some time before being operational. The use of PC's (IBM, Amiga,and Atari) as intelligent display devices is also being explored. The advantage of using terminals is that the standard graphics packages developed for off-line applications can be used with minimal effort by adding a real-time software interface. The disadvantage is the slow response of such a design. Nevertheless, as an interim stage this has proven useful and has given us experience for developing the software support needed in the workstation environment.

The Three Levels of Interfacing

There are three levels (modes) of interfacing to the TRIUMF control system.

Level 1: The data is gathered by an application program on the VAX and stored on disk for later off-line analysis.

Level 2: The data is gathered by an application program on the VAX and stored in an installed global section (memory) for access by semi-online analysis programs.

Level 3: An application program doing analysis spawns a second process which gathers and makes the data immediately available via a shared global section.

Level 1 Case —Radial Probe Scans

The radial profile of the beam current, height, time-of-flight etc. is gathered by an application program running on the VAX and stored on disk. At a later date OPDATA is then used to process this data and display the results. Figure 1. shows the result of using OPDATA to obtain $V \times \cos(\phi)$ vs. energy from a radial probe scan of the time-of-flight vs. radius. Note that only the product of the dee voltage

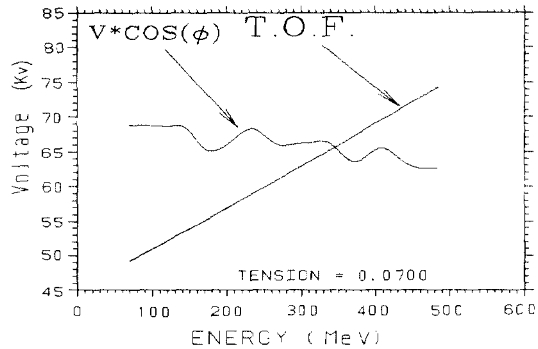

Fig. 1. Time-of-flight radial scan to extract V*COS(φ).

V and the cosine of the particle phase ϕ can be extracted. The phase can be determined using supplementary measurements based on other techniques.

Level 2 Case —Chart Recording

The display of machine parameters as a function of time is often needed. Before the high level routines were available on a VAX these parameters were either displayed on a chart recorder or the data was logged and sent to a remote computer by a slow link for later analysis by a beam dynamics specialist. The impracticability of autoscaling, the unreliability of the chart recorder pens, the need to extract numbers from these traces were just a few of the disadvantages of the chart recording approach. The need for operators to do the analysis required the use of local, user friendly computers. The VAX interfaced to the central control system CAMAC is suitable for this need. With some simple software interfaces to our graphics routines we can now log up to 8 arbitrary devices with a user specified time increment. The data is gathered in an installed global section (of memory) on the VAX in a circular buffer where the display program can access it. Figure 2. illustrates the tracking of 8 thermocouples attached to the rf structure. Programs such as OPDATA can then be used to further analyze (eg. smooth, filter and fit with functions) this data.

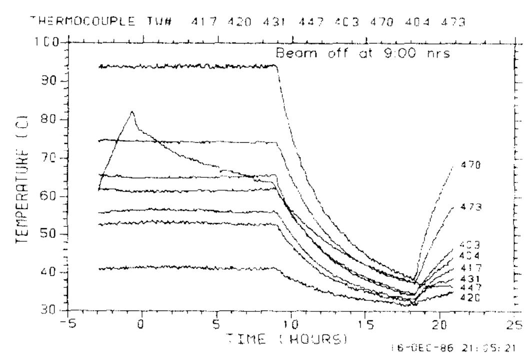

Fig. 2. Display of 8 thermocouples vs. time.

Level 3 Case —The Trim Coils

Phase optimization

The radial profile of the beam phase in the TRIUMF cyclotron is difficult to measure, but the total time-of-flight through the machine is a single parameter which can be readily measured and used in optimizing the phase history. Operationally, trim coil tuning is done blindly, with little indication of the actual phase changes being

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made in the machine. We know that as the time of flight is optimized, the phase oscillations are being damped. To add some light to this situation we have provided an on-line graphics display of the theoretical phase changes introduced by tuning the 54 trim coil pairs, one above and one below the median plane of the magnet. Even if we don't know where we are, at least we *know where we are going*! The modelling of the theoretical phase changes due to alterations in the trim coil settings is based on the original field survey measurements of the radial profile of the magnetic field of the individual trim coils. Since the cyclotron rf frequency and main coil current are usually adjusted during the tuning, their effects are also modelled.

Vertical centering of the beam

A vertically segmented probe can be used to measure the vertical profile of the beam as a function of radius. This data, fed into a computer code is used to predict new trim coil settings which would result in improved vertical centering. Due to the unreliability of the probes, and the fact that the beam height profile is relatively stable and reproducible from one running period to the next, these radial scans are infrequently done. Instead, the beam spill monitors are used as an indication of the quality of this profile. Optimization is done by asymmetric powering of the trim coils to vertically shift the beam position. To aid operators in this axial tuning of the beam, we display, in addition to the phase changes resulting from the symmetric powering of the trim coils, the simulated change due to asymmetric coil excitations. Thus as the trim coils are adjusted the operators can get an immediate and clear indication of the effect they are inducing on the beam.

Problems with the real world

Modelling the real world is seldom a simple task. All of the high level graphics applications are available only on a VAX, but the data base describing the cyclotron devices is maintained by "unfriendly" control computers. This data base contains CAMAC addressing details, data conversion types, scaling types, units, and so on. Whenever a VAX application needs to acquire data directly from a central control system CAMAC based device, all of the necessary data base information must be hardwired into the application program. Software maintenance is a problem because the data base is constantly undergoing small changes and the application programs on the VAX do not automatically get these updates.

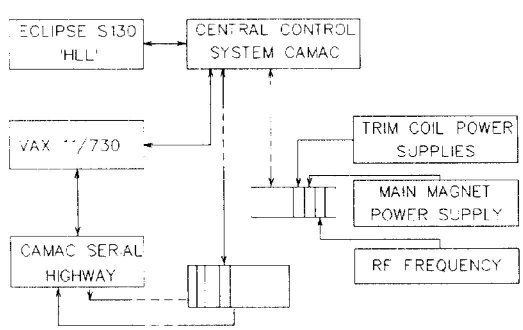

Fig. 3. Data acquisition system for the VAX/730.

Figure 3. illustrates a general layout of the VAX's data acquisition support from a hardware viewpoint. The VAX has its own serial CAMAC highway which is used mostly for offline development. The principle acquisition route is via an interface directly into the central control system's CAMAC executive crate. This provides access to all of the cyclotron's CAMAC based devices. For acquiring data on simple devices such as the rf frequency the VAX has the data base information wired right into the code but this is not the case for trim coils. There are power supply assignments, Br/Bz algorithms and a host of other dynamic and static data base parameters that involve too much maintenance to reproduce in the VAX. In the case of the trim coil Br and Bz data, the control system computer "HLL" gathers the trim coil settings and puts them in a CAMAC memory for the VAX to retrieve. This memory is located in a special CAMAC crate. Special, in so much as the crate is on the serial CAMAC highway where the VAX can read the data via DMA block mode transfers and the crate is also on the central control system parallel CAMAC highway. This crossover is accomplished by running the serial crate using a standard L2 controller and running the parallel crate using an A2 crate controller as an auxillary crate controller.

There is some handshaking between the VAX and HLL to initiate data passing but the process hopefully minimizes the impact on the current functions of HLL. A valued flag which is set by the VAX is polled by HLL which returns the necessary data a) in less than 30 seconds, b) immediately if the operator is making trim coil changes, or c) immediately if a priority request has been made, whichever of the preceding is shortest. A priority request can only result from typing a key on the CIT467 keyboard while the display program is executing. Thus in the passive display mode the data is only refreshed every 30 seconds.

Initially, the power supply current read-backs were so noisy that the model indicated spurious random changes. These read-backs were improved to the point where they are commensurate with the actual observed beam instabilities. The exception is the main magnet coil read-back. Due to the complexity of the control circuitry we use the set-point value to model the main coil current. Inconsistencies in the data base being displayed were also eventually weeded out. It must be emphasized that the *integrity of the data base is of prime importance* else the "garbage-in garbage-out" effect dominates and logged data will be useless for future reference.

By constantly consulting the operators we had, after some 100 programming iterations, not only developed an on-line tuning aid but a tool for looking at past states to help diagnose the present state. Some of the program's features are:

- A color coded, key driven menu of commands.
- In the graphics display of phase and height (z) vs. radius the previous state can optionally be erased (overlay or selective erase modes).
- Superimposed as a separate text plane is listed the full values of the coils currents or their differences from the nominal baseline.
- The current state can be logged.
- The present state or any previously logged state can be selected as the reference.
- Any coil can be deactivated for display purposes (particularly useful for negating uncertainties in main coil, rf frequency contributions)
- Replay of archives either separately or superimposed on the current state.
- Snapshot output to hardcopy devices, including a device independent drawing file which can be edited later for publication purposes (eg. Figure 4.)

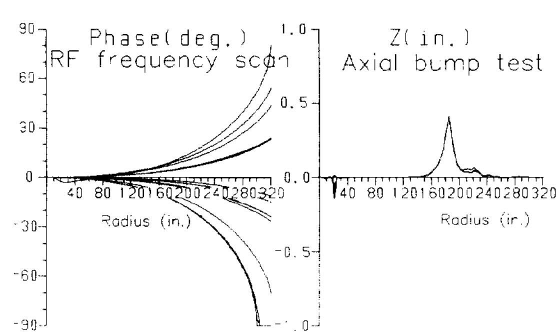

Fig. 4. Display of the trim coils monitor program.

The program is particularly useful in a monitoring situation, where if some trim coil value went astray (inadvertently or not), an immediate *graphical display* of its effect, can be observed. Typical update times are 2—5 *seconds*. Although this performance is slow compared to modern workstations it nevertheless has proven to be a cost effective interim solution.

OPDATA—PLOTDATA—EDGR TRIO

At TRIUMF the Computing Services Group has provided the VAX users with an integrated package of tools written in FORTRAN. The three most commonly used being OPDATA, PLOTDATA, and EDGR. The foundation on which these programs are built is a comprehensive library of graphics routines.

OPDATA

An interactive command driven language designed mainly for the manipulation of dynamic data arrays. Some of the features of OPDATA are:

- Curve fitting, smoothing and plotting
- Data filtering, sorting, binning, summing
- (De)convolution, integration, differentiation, interpolation
- Digitizing data from plots
- Peak finding (manual or automatic)
- Over 100 built-in math functions
- Dynamic allocation of arrays
- Dynamic loading of user written modules
- Built-in EDT and graphical editor EDGR
- Expression evaluation including Boolean logic
- Non-linear fitting of data with any expression
- Flexible input/output of user data arrays (binary, free format etc.)
- Asynchronous trap handler to allow command abort
- Integrated graphics environment
- Session conversation logging
- Save/restore of session (including current graphics environment)
- Macro capability with parameter passing
- Extensive on-line help facility

PLOTDATA

An interactive command driven language whose central function is to produce graphical presentations of numeric data with the following features.

- Flexible input/output of user data
- Density, contour, surface plotting
- Multiple viewports and windows
- Linear operations on data
- Digitizing data from plots
- Bar, pie and tile graphs
- Multiple (>40) fonts
- Built-in EDT and graphical editor EDGR
- Two-dimensional interpolation for sparse data
- Macro capability with parameter passing
- Curve fitting, smoothing and plotting
- Automatic prompting of command parameters
- Forgiving of input errors
- Labels follow the curve on rescaling
- Extensive on-line help facility

EDGR

An interactive facility for creating, editing, manipulating, and storing graphical data. It has been developed primarily for scientific applications, as an aid to preparing graphs and diagrams for presentation or publication. It also provides a device-independent medium of storage for graphical output produced by application programs. It is extensively used in conjunction with the above utilities. Its capabilities are comparable to those of a text editor operating on text files. Graphical elements or images can be cut, pasted, scaled, rotated, translated and included in larger images. Attributes such as colour, line type, or text font can be modified globally or on an element-by-element basis. Magnified views are available on both display and hardcopy. Other functions include area fill, arc generation, text justification and alignment, distance measurement, numerical coordinate input, and overlay of regular grids. Hardcopy output is available on a number of different printers and plotters. Output in a form which can be directly included into a TeX document is also available and was used to prepare this paper. The graphics editor EDGR can be run as a stand-alone program or called as a procedure.

Underlying the above routines are the TRIUMF graphics subroutines. They consist of various drivers, viewporting, windowing, and other low level routines such as AXIS and NUMBER. At an intermediate level we have the GPLOT routines, which are a set of user friendly subroutines for X/Y plotting. For example, to plot X vs Y complete with axes and bring up a menu to allow the current plot to be edited, copied to some hardcopy device etc.

```
C
C  Complete test of GPLOT
C
      REAL*4 X(100),Y(100)
      NPT=100
      IAXIS=3 ! plot data first
      DO 10 I=1,NPT
        X(I)=I              ! Define your own data here
        Y(I)=SIN(2.*I)/10. !   "     "      "
   10 CONTINUE
   90 CALL GPLOT(X,Y,NPT,IAXIS)
      CALL GPLOT_CONTROL(' GPL>',&90)
      END
```

Conclusions

The development of high level graphics routines, originally written for beam dynamics studies for the TRIUMF cyclotron have, after migrating, maturing, and evolving in their application to general graphics problems at TRIUMF have come full circle and are once again being used on home turf. The described application programs and the general utilities OPDATA, PLOTDATA, and EDGR, although implemented on a computer having limited access to the TRIUMF control database, have proven to be useful for machine diagnostics by operators. These utilities have formed a stepping stone for the work to be done on interfacing workstations into the control environment where they will significantly improve the response time compared to using RS232 devices.