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DATA-ACQUISITION SOFTWARE FOR THE HOLIFIELD HEAVY ION RESEARCH FACILITY

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Abstract

A new computer system to perform data acquisition and analysis for the Holifield Heavy Ion Research Facility's Oak Ridge Isochronous Cyclotron (ORIC) and the newer 25-MV tandem accelerator has been under development. This paper presents the current implementation and discusses the design of the data-acquisition/analysis software.

Introduction

As a national facility, the Holifield Heavy Ion Research Facility (HHIRF) serves a large and diverse group of experimentalists. The large number of outside users and the variety of experiments identifies the need for great flexibility and ease of use in the computer system. The system must be capable of serving two on-line experiments simultaneously while a third is being set up. In addition, data analysis and general computing must be supported.

The system, as originally conceived¹, has been implemented around three Perkin-Elmer model 3230 "supermini" computers, supporting independent but identical environments. Each system can comfortably support one experiment and several general computing tasks without degrading time critical operations. Three systems simply and conveniently support three experimental setups.

Software was given careful consideration in light of many requirements. The design contributes to ease of use and learning for the experimentalist, ease of maintenance, and ease of customization from one experiment to another.

Hardware Configuration

The basic hardware components are shown in Figure 1. Each system features 600 megabytes of disk storage, two 6250 bpi, 125 ips tape drives, color graphics terminals and plotters, and CAMAC interfaces. The Perkin-Elmer processors themselves feature 32-bit word length, 4 megabytes of main memory, cache memory, and writable control store.

Two geographically different counting areas, corresponding somewhat to the two accelerators, are serviced by the three computers. In one counting area, systems "A" and "C" are available for use (terminals and CAMAC crates are available). In the other counting area, systems "B" and "C" are available. In this configuration, an experiment may be running from each counting area, on a dedicated computer system, while a third is being set up in either area.

Each counting area contains CAMAC crates which can be shared between computers using auxiliary A-2 crate controllers. An experiment can be moved from one computer to another without physically moving any electronics. An experiment is typically set up on system C, then switched (by software) to system A or B to run.

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Terminals, graphics terminals, and plotters can be interfaced to CAMAC, and therefore can be located anywhere a CAMAC crate is located. These devices can be located in remote areas serviced only by a serial highway.

The vast majority of experiments at HHIRF utilize a locally built, CAMAC oriented microprocessor known as the Event Handler². The Event Handler is cabled to front-end electronics and programmed to recognize an "event", as defined by the experimentalist. On receiving an event signal, the Event Handler reads appropriate ADC's, TDC's, latches, etc. and puts the various parameters together into a (HHIRF) standard format. The event is written to a CAMAC FIFO memory module. The FIFO memory is read continually by the Perkin-Elmer system. This is the beginning of the data stream through the Perkin-Elmer and the beginning of the subsequent software discussion.

Software Structure

The following requirements were made of the data acquisition software:

- * The software should utilize the vendor's operating system as much as possible. This includes multi-tasking and strong real-time support. The data acquisition software should be logically separated into independent programs and should let the operating system handle task switching, time slicing, interrupts, etc.
- * The system should provide an interface for custom programs. User written programs should be able to access the data stream and communicate with a user through a standard structure.
- * Programs involved in acquisition must be able to communicate with each other to synchronize with the data flow and to pass control information.
- * A user interface should allow control over all the software. The user interface should allow the experiment to be monitored and controlled from more than one location by more than one user.
- * The software must co-exist with the vendor's timesharing system. A user must be able to interface with the data acquisition system through any of the standard timeshared terminals.
- * Data acquisition software and off-line analysis software should be designed to work the same and utilize some of the same code. The user should have roughly the same analysis capabilities while he is taking data, and once he learned the data acquisition software, he would already know the analysis software.

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Fig. 1. Hardware Configuration

Fig. 2. Software Configuration

The various functions of data acquisition were broken up logically into these programs:

- (1) Acquisition Program - move data from CAMAC to magnetic tape
- (2) Histogramming Program - histogram samples of the data
- (3) Display Program - display and analyze histogrammed data
- (4) User Interface Program - provide monitoring and control of data acquisition software
- (5) Control Program - provide coordination and communication between all other programs

The software structure is shown in Figure 2. The programs involved with data are termed "acquisition support programs", as they are actually operating on the data. The Control program serves as a control and communication point for the acquisition support programs.

Communication between programs is done by passing messages, a feature of the Perkin-Elmer operating system. A message is received through a program "trap", a subroutine executed when a message is received, with the message as the argument. A message is sent by a FORTRAN subroutine.

The experimentalist interacts with the experiment by running the User Interface program. Each acquisition support program will respond to a set of commands. Any of these commands are available to the user. When a command is typed into the User Interface program, it is sent to the Control program in a message. The Control program re-transmits the message to the appropriate acquisition support program. The support program must acknowledge receipt of the message by passing a message back to the User Interface program via the Control program before another command can be entered.

The Control program greatly simplifies the design in that each acquisition support program and each User Interface program communicates only with the Control program. As a central communications and control point, the Control program can keep track of the entire system.

An important design feature is the capability of user-written programs, particular to some experiment, to sample the raw data from the common memory buffers as they are written to tape for whatever processing is desired. Interaction with the user (input/output) is done with subroutines providing the necessary protocol for communicating with the Control program.

Acquisition Program

The Acquisition program reads events from CAMAC, buffers them into, typically, 8192-byte records, and writes the records to magnetic tape in a (HHIRF) standard format. Part of this format are header records containing date, time, title, tape number, and a copy of the Event Handler program currently in use. This information reflects exactly how the data were produced.

The Acquisition program also assumes responsibility for loading the Event Handler program into the Event Handler. A safeguard prevents data acquisition from beginning without first loading the Event Handler program. Through the Acquisition program, the user can control the data flow to tape and to the Histogramming program. It is worth noting that the user is not allowed to modify the data that goes to tape.

Data transfer rate can be about 300,000 parameters per second from CAMAC to tape. This rate is determined primarily by CAMAC highway transfer rates.

Histogramming Program

The data pass through a memory buffer accessible to all of the acquisition support programs on the way to tape. The Histogramming program samples these buffers for real-time processing of events. This program contains powerful histogramming capabilities for monitoring of the experiment. Some of the capabilities of the Histogramming program are:

- * Any combination of 1-dimensional and 2-dimensional histograms can be produced in memory and on disk, up to 4 mega-channels total.
- * Histograms can be 15-bits or 32-bits per channel or a combination.
- * Up to 1000 histograms can be produced simultaneously.
- * Histogram specifications may include simple gates (up to 1024) and/or free-form gates (up to 80). (A "free-form" gate is a closed, arbitrarily shaped, two-dimensional region in two-parameter space defined by concatenated straight line segments).
- * Histogramming can be performed at a maximum rate of about 10,000 counts per second to disk (slightly faster in memory).

Refer to Figure 3 for data flow through the Histogramming program. Each event is expanded from its tape format into an array, one parameter per array element. The array is passed to an optionally-supplied FORTRAN subroutine, USERSUB. The user can supply his own customized routine here for whatever event-by-event processing he desires. This routine may manipulate the parameters of the event or calculate new parameters to be histogrammed. If no customized processing is needed, USERSUB is a dummy routine which does nothing.

The user can exercise control over his customized USERSUB through a "user command processor", USERCMP. If the user supplies this routine, he is able, through the standard User Interface program and Control program, to direct commands specifically to this routine to control/monitor his USERSUB. From one experiment to the next, USERSUB and USERCMP are the only routines which typically require changes.

After USERSUB, the event is passed through gate tests previously defined by the user. A parameter to be histogrammed whose gate conditions have been met is translated into a disk (or memory) histogram address and passed to sorting routines¹.

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Fig. 3. Histogramming Program Data/Control Flow

The Histogramming program is identical in operation to the standard off-line tape scanning program. Customization is performed exactly the same way, utilizing USERSUB and USERCMP. The capabilities of the off-line version are the same as described above with the exception that up to 16 mega-channels can be histogrammed on disk.

Display Program

Histograms produced by the Histogramming program, in memory and on disk, are accessible by the Display program³. This program has extensive display and analysis capabilities and, like the Histogramming program, is essentially the same program used for off-line data display and analysis. The program drives a Chromatics color graphics terminal with 512 x 512 pixel resolution and a color plotter with 1024 x 1024 resolution. Some important capabilities of the Display program are:

- * Display of 1-dimensional and 2-dimensional histograms.
- * Peak finding and fitting.
- * Simple slice and free-form projections from 2-dimensional histograms.
- * Interactive graphic construction of free-form gates.

Control Program and User Interface Program

These programs together provide control of the acquisition support programs. The most important function is to provide a single user with communication paths to each acquisition support program. All communication must pass through the Control program for re-transmission. By virtue for this design, it is also possible to have more than one user monitoring/controlling the experiment. It is often the case that between the computer room, counting room, and experimental room, the experiment must be watched from more than one place.

The entire system is initiated by the User Interface program. If no other programs are running, the user can enter the command to start the Control program. The user must supply the Control program with a software configuration file, which contains the following information:

- * The names of the acquisition support programs to run.
- * The commands that are valid input to each program.
- * The priority at which each program should run.

The Control program starts the specified programs and informs the user when all is ready.

The control program can kill and re-start any of the acquisition support programs without affecting the others. For example the Display program can be killed when not in use to increase available memory. The user interface program itself can be ended without affecting data acquisition.

A log is kept by the Control program, recording on disk all dialog between the user and the acquisition support programs. This is helpful in diagnosing problems and recording milestones during the experiment (scalar readouts for example).

Summary

In operation, the system performs at least as well as anticipated. The most noticeable advantages of the hardware and software design are:

- * A standard data format between the Event Handler and the Perkin-Elmer systems and a standard data tape format mean standard analysis programs and simpler debugging.
- * Shared CAMAC crates facilitate switching of 3 experimental setups between 3 computers and provide convenient access to computer system devices.
- * Data acquisition software does not interfere with or preclude other computing on a computer system.
- * Acquisition support programs which are standard, powerful, and customizable result in less programming for the experimentalist, fewer bugs in the software, and less education to take data.

References

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