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TITLE: MAGNETIC-FUSION DATA ACQUISITION AT LOS ALAMOS

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Magnetic-Fusion Data Acquisition at Los Alamos

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The CTR division uses a single software package to acquire data from hundreds of CAMAC recorders. For the past five years, this package has been used by all experiments, both manual and computer controlled. A variety of signals are stored in transient digitizers and other memories. The computer retrieves the data and applies an efficient compression algorithm before storing it on disk. The physicist can plan his next shot from the acquired data even as the rest is read. The readout is list-directed with device, amplifier, and time base types and their settings selected by the physicist. A new experiment may be set up in minutes.

INTRODUCTION

Before the development of this acquisition software, each CTR experiment at Los Alamos had its own acquisition system and file format. This state made software maintenance difficult. At least one programmer had to be familiar with each system and analysis programs could not be transferred without change between experiments.

With these problems in mind, new data acquisition, analysis, and display programs were designed. In these programs, called DAD,[1] all experiment and device-specific information is in descriptor files. This separation allows the same program to be used for all experiments.

I. HARDWARE

The computer systems used are:

1. A mini to control each machine.

2. A mini to acquire experimental data.

3. A large mini for immediate analysis.

4. A main frame for more extensive analysis and larger archiving capability.

5. A satellite link to the DOE/MFE computer center at the Lawrence Livermore National Laboratory (LLNL). The large scale Cray and CDC

computers there are used by the experimentalists primarily for electrical network analysis and modeling.

Individual computers sometimes serve multiple functions among items 1 to 3. The largest experiment is ZT-40M, a reversed field toroidal z-pinch. It has a Prime-750 that does control, acquisition, and on-line analysis. The Compact Torus Experiment (CTX) and the Field Reversed Experiment (FRX-C) share a Prime-400 for acquisition and analysis. Each has a Prime-300 for control of their machine. The toroidal z-pinch prototype (ZT-P) is served by a Prime-400 with some control by LSI-11 microcomputers.

An X.25 link between the ZT-40M computer and the VAX cluster gives rapid transfer of data from the experiment to a larger data base.

A PRIMENET link of ZT-P and ZT-40M permits sharing of resources including programs and computer hardware.

II. DESCRIPTOR FILES

The descriptors are of four types: logical device, time base, diagnostic, and shot.

Each logical device descriptor has the model or type of the data acquisition device, its CAMAC address, the physical units measured, and a scale factor between the recorded signal voltage and the measured value. The amplifier and time base are also described. The total entry may have additional floating point numbers that are defined by the user. Typical uses are for probe positions or wavelength settings in a diagnostic or for a calibration reference. Most data collection is with analog-to-digital transient recorders with memories up to 32k samples.

A time base descriptor may "gang" many devices to one set of numbers. This may be an external clock. The sample rate and number of samples are given for each rate. The devices used are listed for cross-reference.

A diagnostic descriptor lists all logical devices associated with a given diagnostic and the status of the diagnostic. This status marks if the group of logical devices is to be ignored, read but not kept beyond the next shot, or read and archived.

The shot descriptor has data that applies in common to all devices such as the shot number, time of day, voltage settings, fill pressures, and time delay settings.

These tables are kept up-to-date using a utility program called DUTIL. This interactive program can be used by anyone associated with that experiment. With this program, the user can define new devices and diagnostics or change the tables of existing ones. In our experience, this open system approach has worked well, and is an important factor in the acceptance of the system by its users.

To set up a total data set for a different experiment, we must create a disk directory with the name of the experiment, create an empty set of descriptor files in the directory, create an area for archived shots, and begin filling in the descriptors using DUTIL. An "experiment" may be as large as ZT-40M or a single recording device on a serial highway in a remote laboratory.

III. DATA ACQUISITION COMMANDS

The data acquisition commands of DAD are ARM, BASE, CLOSE, OPEN, READ, SAVE, and TRIG. The OPEN and CLOSE commands lock and release the descriptor files. The BASE command reads recorders when the signal is inactive (base line) and, if possible, reads them with no input (open circuit) to measure absolute voltages. The ARM, BASE, READ, and TRIG (trigger) commands may be changed by arguments that restrict them to one diagnostic set or a single logical device. The programs now support many different hardware models and operational modes: 24 types of logical devices, 5 types of amplifiers, and 5 types of time bases.

The pre-shot sequence of commands is:

OPEN, ARM, TRIG, BASE, ARM.

This sequence takes a base line and prepares the recorders for the shot. After the machine trigger, the post-shot command sequence is:

READ, SAVE, CLOSE.

This records the data from all "active" diagnostics in a temporary shot file and archives the data from each diagnostic with a "save" status. These commands may be executed only by a program having the full rights of the experiment. Anyone can use the commands for data analysis and viewing.

For an experiment that is not computer controlled, these sequences are requested interactively. To simplify things for the manual user, any sequence of commands can be associated with a number and then be invoked by using only that number. These definitions and the parameters used by the DAD routines are retained in personal files. For an experiment that is computer controlled, the sequences are invoked from command files.

The experimenters may check a recorder by cycling it and displaying any test input or they may see the range of data values to adjust an input offset or to check for noise. While the experiment is collecting data, the devices are off-limits.

IV. DATA COMPRESSION

Data compression is normally part of the READ command processing. The data may be unpacked (one item in each computer word), packed into a bit stream (using a word size that depends on the device), or compressed. The choice used is controlled device-by-device by an entry in the logical device descriptor.

The unpacked technique minimizes CPU time at the expense of file size and disk input/output (I/O) time. The packed technique costs about 50%

more CPU time than unpacked but results in a predictable reduction in the file size.

The compression technique records differences between successive data inputs and uses about three times the unpacked CPU time but results in a reduction of the total shot file size by a factor of three to six. Table I shows the number of bytes stored for a typical device.

For compression to be effective, the data must change slowly. Each data trace is differenced to get a starting value and the successive changes. If it changes slowly then those changes will be small and can be stored using fewer bits per data item. The algorithm scans the trace to make divisions into groups that will minimize the total bits needed. As a

Table I. Storage for a typical 10-bit device.

saved descriptor	188	bytes
optional words	4	
unpacked data	16384	
packed data	10240	
compressed data	2400	

compromise to reduce the time used, it projects ahead only one group. Each group is preceded by an item count and the number of bits used to represent each item.

The system has the flexibility to defer the data compression until SAVE time or until off-hours. It has been our experience, however, that the elapsed real time to compress the data during the READ processing is not significantly more than that for unpacked or packed data because the disk I/O time is greatly reduced.

The expansion of compressed data takes more time than using unpacked data but that extra time is only about 10% of the simplest retrieval and is often less than that needed for packed data. Data compression also allows more shots to be available on disk before transfer to permanent storage and the I/O time is reduced.

On our largest experiment (ZT-40M), a typical shot has 1.4 million items from 220 devices used by 26 diagnostics. The READ and SAVE takes 200 seconds and 700 compressed shots are stored on disk.

V. SUMMARY

The separation of device descriptors from the programming allows the use of one set of programs on a variety of experiments. The compression of data permits reduced storage and expanded availability of older shots with a small real-time penalty.

[1] K. A. KLARE, "Magnetic-Fusion Data Analysis at Los Alamos," submitted to these proceedings.