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TITLE: MAGNETIC-FUSION DATA ANALYSIS AT LOS ALAMOS

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Magnetic-Fusion Data Analysis at Los Alamos

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DAD is a versatile, easy-to-use, easy-to-modify set of programs for Data Analysis and Display. The physicist simply calls a program by its name and a few numbers, which will tell the device, shot, or operation needed. Each command invokes a separately compiled program. This allows each experimenter to write commands to display model calculations or particular devices. Typical displays include: raw and normalized signals, or derived results such as phase-modulation detection Thomson scattering nonlinear fits, wall temperatures from thermocouple conversions, and ion temperatures from Doppler broadening of spectral lines. Multiple-device and multiple-shot displays of single-channel or quadrature signals show progressions otherwise hard to find. Some programs have three-dimensional displays with contour or surface plots. The snots available on disk and device settings during data recording can be listed; analysis parameters may be shown or set. One number can define a whole series of commands.

ODD is a calculator-like program to quickly process data and graph resul ; for user needs that have not been reduced to a standard program. These programs use a shared library or Prime and VAX computers.

INTRODUCTION

The acquisition, analysis, and display of magnetic-fusion data in the controlled thermonuclear research (CTR) division at the Los Alamos National Laboratory use DAD and ODD. The data acquisition programs of DAD are described in a companion paper.[1]

The Data Analysis/Acquisition and Display (DAD) program is a connected set of programs with a single command interpreter to dispatch requests. Some requests are handled by the interpreter; most requests are for other separately compiled programs. One set of these generally available programs is continually being expanded.

The Other Data Display (ODD)[2] program is modeled on a calculator but usually operates on 1024-dimension vectors of experimental data. ODD works interactively or from command files and has more than 200 commands including mathematical functions. It allows user constructions in a simple language of specialized programs not available in DAD.

DAD and ODD use a common library of retrieval, mathematical, and graphical functions. This DADLIB library is shared by all users.

I. DAD

The programs collectively known as DAD use "chaining" to couple the command interpreter to any requested program. Commands are letters naming the program and up to 12 numbers. For example, the command "N 109" will display the normalized current trace on the ZT-40M experiment. Selection of the shot is by a command that changes that value in a file of such parameters.

Multiple commands may be given at once by separating them with semicolons. A command line preceded by a number can be invoked again with just that number. A loop can thus be formed by having the command invoke itself. The loop continues until a limit is reached or some error condition happens like going beyond the current shot number.

Users work from terminals, which may access any of the data repositories through a GANDALF port selector. They set desired parameters in a file in their own directory. These parameters control the flow and settings of all programs.

II. THE STANDARD DAD COMMANDS

The parameter file can be: inspected (PA), compared with the current values for the experiment (DAD), or changed by item (SET). The user can set all his plot limits (FL) or increment the reference shot (UP and DOWN).

The terminal is managed through the parameter file or when needed erased (ERA), returned to scroll mode (FIN), hard copied (HDC), or printer ejected (EJE).

Commands may list information on: the shot header containing basic machine parameters like the bank voltages, fill pressures, and delay times (HEAD and VPf), the sets of diagnostics of a shot (DI), the logical devices used for acquisition on a shot (LD), the diagnostics, devices, and number of items stored (CONTENT), the shots available on disk (SH), the program names (L), or the help files (H).

Some DAD commands may have several options; for example, the normalized data display (N) may also ratio two devices (NR), smooth over a specified number of data values (NS), integrate (NI), differentiate (ND), or list the numerical value (NL). Other programs show the same trace for several shots in three dimensions (LDSH),

view raw data (V), or plot one trace or ratio against another (XY).

III. THE DAD ANALYSIS PROGRAMS

One program infers from probe data the magnetic field (BF), excluded flux (EF), or flux radius value (RF). Another converts small thermistor recordings into Celsius (ST).

Heterodyne phase angles are derived using an arctangent computation of quadrature signals from the demodulated output of an interferometer (QI). Options allow selection of self-centered circles or two forms of elliptic distortion of the derived Lissajous pattern input to the arctangent computation. This program has been used for interferometry[3] and for measurement of current by Faraday rotation in a surrounding fiber optic cable.[4] The results from multichord measurements may be given in two- or three-dimensional plots of raw, fitted, or Abel-inverted data The multichord displays can be used even with non-quadrature devices like plasma luminosity.

The Doppler shift of plasma-generated spectral lines is converted to ion temperatures (TI). The electron temperature derived from single-point Thomson scattering with finite

acceptances and relativistic corrections requires
a nonlinear fit (TS).[5]

A phase-modulated signal without a reference
signal can be converted into phase angles (WW).
A unique four-point algorithm removes base line
and amplitude changes and works for phase
modulation on time scales comparable to the base
frequency.[6,7]

Programs and displays for any given
diagnostic may be written by the physicist who
uses its results. His own program can then be
invoked with all the features of DAD and made
universally available. (Less complicated
programs may be conveniently handled by ODD as
described below.) The DAD programs may
eventually prove useful to other experiments when
the same data are available there. For example,
an energy-radiated calculation may be used
immediately when a bolometer is installed.

Each of these programs returns to the
interpreter when it finishes. Thus, effectively,
the user has a big program with many commands but
has to edit only a small program if there are
errors or changes.

IV. ODD

The ODD program is designed to offer a simple means to do problems analogous to but beyond the scope of a hand-held calculator. It can manipulate arrays and produce plotted results. It uses reverse Polish notation to carry out calculator-style commands entered on a terminal. It can retrieve experimental data and uses the graphic capabilities of the terminal. ODD is also useful for anyone wanting a calculation of simple-to-moderate complexity even if that problem does not deal with experimental data.

ODD uses a four-level stack of 1024 (or 4096) numbers with internal summation registers and any number of files used for temporary storage. It also has a scalar mode. Its functions include arithmetic, comparison, trigonometric, Bessel, transformation, and stack manipulation. A finite Fourier transform can filter or analyze the frequency spectrum.

Graphs of data versus time, other data, frequency, or time offset may show any number of curves for 12 boxes with adjustable or automatic plot limits. Each curve may have a different symbol, dashing, and color.

Programming is from the terminal or a file and is interpreted as it is read. Branches, condition tests, and loops are available. Settings control the graphics limits. Ten lines of ODD may do what 100 lines of FORTRAN coding would. Because it is more condensed, ODD programs can be difficult to read.

The time required to invoke programs in ODD is small because all the commands are built-in. On the other hand, an interpreter can limit the speed or scope of problems solved. Here the physicist must choose according to his problem.

V. THE DADLIB LIBRARY

The graphical, retrieval, and mathematical functions of DAD and ODD are found in the DADLIB library.

The library supports an extended version of Tektronix PLOT-10 with other terminal models and faster output. Most programs, however, use routines from a simpler graphics set. These routines provide for any number of screen boxes and permit three-dimensional contour and hidden-line surface plots.

The machine dependence of input/output statements is masked by a set of calls. Assembly language routines pack and unpack experimental data; all other programs are FORTRAN.

To support DAD programs and ODD's functions spline fits and mathematical functions are offered. The subroutines for retrieval of stored experimental data define the experiment, shot, diagnostic (if needed), and device number. Other calls return time, data, and probe arrays or label the page.

VI. SUMMARY

The DAD and ODD programs using the DADLIB library permit the fusion physicist to examine experimental data in many different ways. This variety satisfies a wide range of experience and need. The programs can be supported by a small computer staff, while permitting the physicist to work directly with his data with little computer instruction.

ACKNOWLEDGMENTS

DAD received many useful ideas from R. W. Wilkins and P. L. Klingner. The ODD concept came from the ODDBALL program.[8] ODD and DAD have benefited from the suggestions of many users.

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[8] R. W. McGaffey, "User's Manual for ODDBALL, ORMAK Device Data Base Analyzing Lukasiewicz Language," Oak Ridge National Laboratory report ORNL/CSD/TM-24 (January 1977).