SOFTWARE FOR A DATABASE-CONTROLLED MEASUREMENT SYSTEM AT THE FERMILAB MAGNET TEST FACILITY

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Abstract

A software system has been developed for use in measuring the magnetic properties of accelerator magnets at the Fermilab Magnet Test Facility. Key features of the system include:

- Storage of measurement data in a relational database.
- Use of database tables to define the individual steps that occur during a measurement.
- Use of an "electronic logbook" to store an historical record of important measurement details within the database.
- A graphical user interface for measurement technicians and data analysts to use in acquiring and analyzing data.

Other papers describe the preliminary software design [1], the design of the database tables [2], and the results of measurements obtained using this system [3] [4]. This paper describes the final software system design, with particular emphasis on the data acquisition subsystem.

Currently, the system supports 3 test stations and has been used to measure approximately 85 magnets. It is used for both production measurements and R & D studies of prototype magnets.

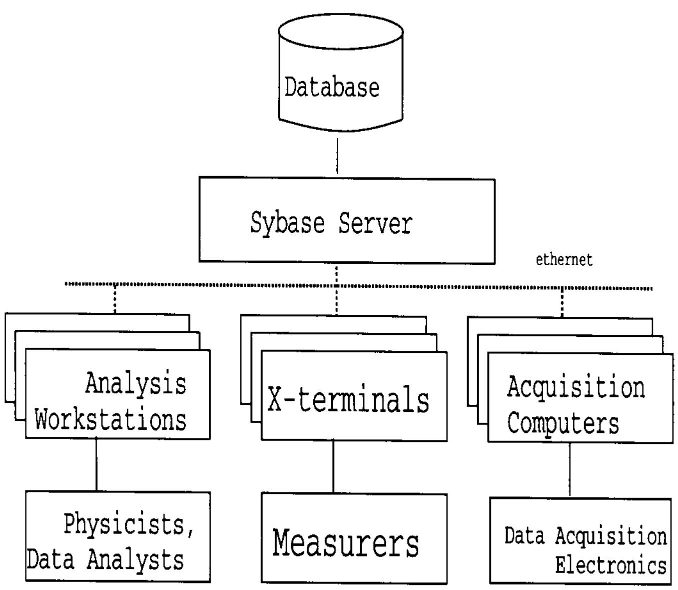

Figure. 1. System Overview

I. SYSTEM OVERVIEW

As shown in Figure 1, the system consists of a network of distributed computers. A commercial relational database system, Sybase[1], is at the center of the system. Sybase is based on the client/server computing model. The Sybase server, which runs on a workstation that is dedicated for that purpose, manages the storage of data into and retrieval of data from the database. Requests for storage and retrieval of data come from client programs, which run on other workstations in the network.

Three types of client programs are used to access the database:

- General Purpose Clients provided as part of the Sybase relational database system. These clients allow for report generation, data entry, table browsing, etc.; they run on any of the analysis workstations.
- Data Acquisition Clients, written at the Fermilab Magnet Test Facility, which control data acquisition electronics and store measurement data into the database. These clients run on the acquisition computers.
- Data Analysis Clients, written at the Fermilab Magnet Test Facility, which perform post-acquisition data reduction and comparison of final results with expected results, storing the final results into the database. These clients run on any of the analysis workstations.

A. HARDWARE ENVIRONMENT

The workstations shown in the system overview are SPARCstations[2]; these are used by physicists and data analysts in an office environment. X-terminals are used by the measurement technicians to interact with the system; they were chosen over workstations to minimize system administration, and to avoid potential problems with the use of disk-based computers in a testing environment that includes dust and strong magnetic fields. The data acquisition computers are diskless implementations of Sun SPARC computers contained on a single-wide VME board.

The acquisition electronics consists of a mixture of VME, VXI and GPIB data acquisition and control devices.

B. SOFTWARE ENVIRONMENT

All of the computers used in the measurement system run SunOS (Solaris 1.1). The X-windows/Motif environment is used to provide a graphical interface as well as text-based windows for interacting with the system. Plotting of data is achieved us-

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[1] Sybase, Inc. 6475 Christie Ave., Emeryville, CA, 94608
[2] Sun Microsystems, Inc. 2550 Garcia Avenue, Mountain View, CA, 94043

ing programs that provide plotting capability in the X-windows environment (PAW[3], gnuplot[4]).

Code developed at Fermilab for this system is written almost exclusively in C; a few computational subroutines are written in FORTRAN.

Programs that access the database do so, at their lowest level, through Sybase's Open Client C programming interface. To simplify the programming interface, however, a layer of subroutines is built on top of the Open Client C interface. These subroutines, which allow reading data from the database, inserting data into the database, and updating data in the database, use variable argument list processing to provide access to data in tables of widely different format and content.

II. THE DATA ACQUISITION PROGRAM

The data acquisition program reads and controls measurement electronics, displays data plots, solicits required input from measurement technicians and stores acquired data into the database.

The data acquisition program is designed to achieve the following goals:

- allow varying measurement control parameters for different types of magnets or for special R & D test requirements. Examples of measurement control parameters include: the devices used for a given measurement, the list of currents at which to perform measurements, the range of probe positions at which to perform measurements, etc.
- allow exact repetition of a previous measurement, either for purposes of measuring similar magnets in an identical manner, or to verify the validity of a previous measurement.
- provide an historical record of important measurement parameters, such as the devices used in each measurement and the calibration parameters used to convert data to engineering units.
- store measurement results in a well-organized, efficient format, allowing data analysts to discern trends in measurement results or to detect problems with measurement electronics.

The database is used as a framework for achieving these goals. It is used to store not only the data obtained as a result of measuring a magnet, but also the prescription for and record of how the measurement is performed.

To accomplish the first two objectives listed above, a measurement must be decomposed into a sequence of steps, e.g.: ramp the magnet current, change probe position, measure field, store data. Once the individual steps are identified, a mechanism for assembling the steps in different combinations must be provided. To ensure that a given measurement can be repeated exactly, a means of storing the combination of steps used for a measurement must be provided.

The data acquisition program uses the database to store the list of steps that prescribe a given measurement. Each step is called a "checkitem", and the combination of steps is called a "checklist". A checklist can be either a collection of steps executed together in a specific order, or a list of steps in which a single measurement parameter is varied (in the manner of a programming loop). A checklist can itself be a checkitem in another checklist, which allows for nesting of steps as well as reuse of a collection of steps.

[3]R. Brun et al., Physics Analysis Workstation (PAW) Reference Manual, CERN preprint Q121, 1989

[4]Colin Kelley, Thomas Williams, et. al available via ftp from dartmouth.edu

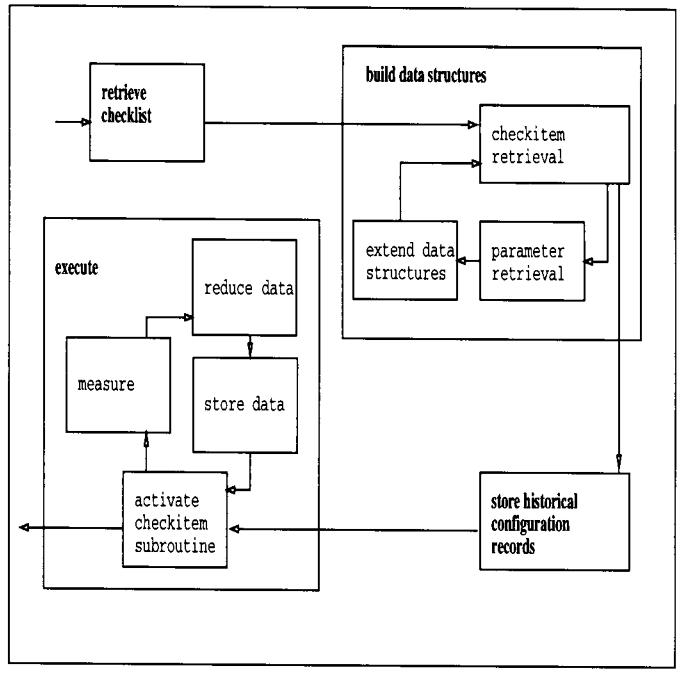

Figure. 2. State Diagram of Data Acquisition Process

Figure 2 illustrates the states that the data acquistion program executes while performing a measurement. It begins by retrieving the checklist from the database. As the checklist is retrieved, data structures are built in program memory to contain various items required to control how the measurement proceeds. These data structures include:

- a linked list of structures identifying the steps (checkitems) taken to perform the measurement.
- a linked list of structures specifying the instruments used to accomplish the measurement. An instrument is a collection of measurement devices designed to measure or control a single measurement variable, such as field strength or magnet current.
- structures associated with each device that identify the method of converting data from the raw output of the measurement devices (volts, counts, etc.) to more meaningful engineering units (Amperes, Tesla, etc.).

Once these data structures are constructed, the program creates entries in appropriate database tables to provide an historical record of:

- which checklist was used to acquire the data.
- which instruments were used during the measurement.
- which sets of calibration parameters were used during the measurement.
- any special comments entered by the measurement technician to describe the measurement.

At this stage, the data acquisition program is ready to execute the sequence of measurement steps prescribed by the individual checkitems in the checklist. Each type of checkitem has a subroutine that performs the processing requested by that type of checkitem. The program runs the measurement by working its way through the linked list of measurement checkitems and calling the appropriate subroutine for servicing each checkitem, until the measurement is complete.

As the measurement proceeds, data is recorded into tables organized to separate "raw" data (as output from readout devices) from reduced data (data converted to engineering units). Data collected under a specific set of measurement conditions are stored in the database as "runs", while a set of runs taken under similar conditions is stored in the database as a "sequence".

The data obtained and stored by the data acquisition program may require further processing to provide useful information for physicists examining the data. Data analysis programs, which are described in the next section, perform this processing.

III. DATA ANALYSIS PROGRAMS

Data analysis programs are used to derive measurement results in the form most meaningful to the physicists who study the data and to store the derived results into the database. They also provide a means of testing the measurement data against the expected results for the type of magnet tested.

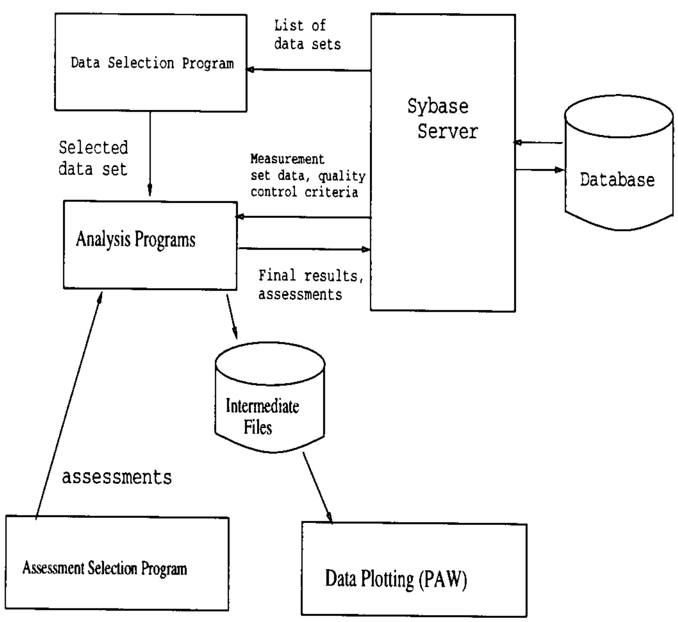

Figure. 3. Block Diagram of Analysis Programs

Figure 3 shows a block diagram of the programs that participate in data analysis. The data selection program is an X-windows application that queries the database for a list of measurement sets to analyze and allows the measurement technician to select a data set from the list. The data selection program then activates one of several analysis programs, passing an identifier for the selected data set.

The analysis programs retrieve measurement data sets, using the set identifier to locate the data in the database. After retrieving the data, the analysis programs process the data into the appropriate form, write intermediate data files, and start up the data plotting program, PAW, to present the data in a graphical format. Another program, the assessment selection program, is started at the same time as the data plotting program. This assessment selection program allows the measurer to provide an assessment of the quality of the data while viewing the data plots.

Once all of the data has been assessed, quality control criteria are retrieved from the database. The quality control criteria identify the expected results of measurements; measurement results are compared to the quality control criteria to determine whether there is a problem with the magnet or with the measurement. Results are stored into the database, along with a summary report of the measurement results that fail the quality control comparisons.

IV. CONCLUSION

A measurement system based on a relational database has been developed and used to test magnets for the Fermilab accelerator. The system provides:

- database-driven measurements, eliminating the need to develop new code when measurement steps change.
- flexibility in meeting the requirements of R & D measurements of prototype magnets as well as routine measurements of a variety of production magnets.
- integrated storage of measurement results, measurement control parameters and commentary information in a relational database, enabling better interpretation of the effects of measurement procedures on measurement results.
- efficient measurement of magnets, allowing testing to keep pace with magnet production as well as providing timely feedback to the magnet production process.

References

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[4] D.J. Harding et al. Magnetic Field Measurements of the Initial Production Main Injector Dipoles. In *Procedings this conference.*