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DIII-D physics analysis database

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Since June 1986 the DIII-D tokamak has had over 16000 discharges accumulating more than 250 Gigabytes of raw data (currently over 30 Mbytes per discharge.) The centralized DIII-D databases and the associated support software described earlier provide the means to extract, analyze, store, and display reduced sets of data for specific physics issues. The confinement, stability, transition, and cleanliness databases consist of more than 7500 records of basic reduced diagnostic data datasets. Each database record corresponds to a specific snapshot in time for a selected discharge. Recently some profile datasets have been implemented. Diagnostic data are fit by a cubic spline or a parabola by the in-house ENERGY code to provide density, temperature, radiated power, effective charge (Z_{eff}), and rotation velocity profiles. These fits are stored in the profile datasets which are inputs for the ONETWO code which computes transport data.

INTRODUCTION

Since June 1986 several timeslice based physics analysis databases have been accumulating data from the DIII-D tokamak fusion experiment. The set of databases is called YOKA from the Japanese word for good. Four of the YOKA databases address the major plasma physics issues of confinement, stability, L- to H-mode transitions, and impurities. Other databases deal with rf heating, MHD fluctuations, and ITER H-mode studies. Recently, profile information has begun to be integrated into the YOKA databases. The in-house ENERGY code fits database diagnostic data to provide the database profile information.

Section I outlines the YOKA database architecture, its current status, and its success in meeting the original design goals. Section II gives an example of information flow from raw data to a database entry. Section III describes the integration of plasma profile information into the YOKA databases. Section IV discusses future plans for the YOKA databases.

The YOKA databases are implemented using the S1032 database management system from CompuServe Data Technologies running under VMS on a DEC VAX 8650.

I. DATABASE OVERVIEW

The YOKA database architecture is meeting the original design goals discussed previously.¹ Data traceability is provided by using a centralized D3PHYS account with incremental daily backups and by including analysis code identifiers and input parameters in database entries. Data integrity is ensured by using range checks for all

database parameters and by restricting updates of D3PHYS files to authorized users. The modularity of subexperiment subdirectories and datasets described later in this section allows flexibility in configuring databases or in adding new subexperiments, datasets, or databases as new experiments come on line or as plasma physics studies shift emphasis. Automation of most database related tasks as described in Section II means a full time database administrator is not needed.

Details of the YOKA database design implementation have been presented elsewhere.² A brief summary is included here. A dedicated VMS account called D3PHYS owns the YOKA databases, reduced data files, and the data analysis programs. For each DIII-D diagnostic, D3PHYS contains a subdirectory which contains the source, text, and executable files to analyze that subexperiment's data and produce a reduced data file called a YOKA file. Each record of a YOKA file corresponds to a particular timeslice from a particular DIII-D discharge. The parameters in a YOKA file are specific to its corresponding subexperiment. In addition to the output values from an analysis code, the YOKA file includes input values necessary and sufficient to redo the analysis.

Taking advantage of VMS task-to-task capabilities, in-house utilities consisting of DCL procedures and FORTRAN programs allow authorized users to update the D3PHYS analysis codes or to transfer YOKA files to the D3PHYS area for inclusion in the databases. Each subexperiment has a different authorized user, typically the physicist responsible for that diagnostic. A single D3PHYS subdirectory accumulates YOKA files from all subexperiments.

Figure 1 shows some of the D3PHYS subexperiments and databases and how S1032 database management system "datasets" comprise a database. For each subexperiment there is an S1032 dataset whose definition file is kept in its subexperiment's D3PHYS subdirectory. Each record in a dataset corresponds to a particular timeslice from a particular DIII-D discharge. The dataset definition for a subexperiment contains the same parameters as that subexperiment's YOKA file. In addition to subexperiment specific parameters, all datasets contain the parameters SLICE, EXEID, and ENTRY_DATE. SLICE is a text string concatenating the discharge number and timeslice. EXEID is the identification of the executable code used to create the record. ENTRY_DATE is the date and time of the record entry.

Each YOKA database has a dedicated D3PHYS subdirectory which contains the datasets comprising that database. Every database contains a good-shot-list (GSL) dataset which is used to enter new records as described in Section II. The datasets are joined by the common keyed attribute SLICE. Each YOKA database concentrates on a different plasma physics issue. Therefore, the configuration of datasets may be different for each database, and, typically, the SLICE entries are different in different databases. For example, the L- to H-mode transition database lacks an MHD fluctuations dataset but the confinement and stability databases each contain an MHD fluctuations dataset.

The YOKA databases have been an invaluable tool for reducing 250 Gigabytes of raw data from over 16000 plasma discharges to a manageable set of reduced diagnostic data currently consisting of about 7500 timeslice records. The number of parameters in a dataset varies from five to fifty depending on the dataset. Furthermore, a dataset

Fig. 1. Integration of profile information into the DIII-D physics analysis database structure.

parameter may be defined as an array. Typically there are about twenty datasets per database with a total of close to 2000 parameters per timeslice record.

II. FLOW OF DATABASE INFORMATION

Figure 2 shows a typical flow of data from the DIII-D data acquisition system to the YOKA databases. During tokamak operations, that day's analysis coordinator keeps a record of the day's experiment with an interactive shot log program. The shot log program keeps timeslice based entries. The analysis coordinator may designate any timeslice as "good" by specifying a target YOKA database for that timeslice. A "good-shot" comment may also be entered. At the end of the day's operations the shot log program scans the shot log for timeslices with YOKA database entries and creates a GSL file containing the discharge number, timeslice, target database, and "good-shot" comment. The analysis coordinator then inspects and/or modifies the GSL file and sends it to the D3PHYS area.

A D3PHYS batch job runs every night to update the YOKA databases. If there is a new GSL file its entries are entered in the GSL datasets in the target databases and messages specifying the new timeslices that require analysis are sent to the users responsible for analyzing each subexperiment's data. However, if the new GSL file is from the current day, its entry into the GSL dataset in the target database is deferred one day. Instead batch jobs are submitted on behalf of the appropriate users to analyze those timeslices and create YOKA files in the users' areas.

Regardless of the GSL file status, data from any newly submitted YOKA files is entered in the corresponding dataset. The target database is determined by checking for a timeslice value match between the YOKA file record and a GSL dataset entry. If no match is found, that YOKA file record is ignored. If the EXEID value in a YOKA file record indicates the analysis was performed by a non-D3PHYS code, that entry

Fig. 2. Information flow to and from the DIII-D physics analysis database.

is ignored. If a data value in a YOKA file timeslice record is out of range it is set to MISSING in the database. Other parameters for that timeslice may be accepted. Success and error messages are sent to the appropriate users.

The D3PHYS batch job performs other tasks. It checks that database data dependent on other database data is consistent. A text report file for each database is created weekly. For each database an input file for the in-house database plotting program is created daily.

Thus, all updates to the YOKA databases are automated except for intentional quality control whereby physicists may inspect and/or correct YOKA files before submitting them to the databases. Each morning the most recent database updates are available.

III. IMPLEMENTATION OF PROFILES

Plasma profile information is being incorporated into the existing YOKA database architecture. The ultimate goal is to have a centralized, self-consistent, and easily accessible repository of DIII-D data to address physics issues concerning plasma transport and confinement. Electron density and electron temperature profiles have been implemented recently.

The ENERGY code is the analysis program which calculates profiles. Figure 3 is a coarse ENERGY code flow chart. Figure 3 includes the intermediate code used to create profile YOKA files described later. The ENERGY code can be run in several modes (and fit different types of profiles) sequentially. For example, it can calculate an electron density profile using Thomson scattering subexperiment data only or CO₂ interferometer data only or both. Other modes calculate electron temperature, ion temperature, radiated power, Z_{eff} , or plasma rotational velocity profiles using one or more of the appropriate diagnostic subexperiments. Cubic tension spline fitting or parabolic fitting may be specified.

The ENERGY code maps diagnostic subexperiment data from known locations in physical space (R,Z) to plasma equilibrium flux space described by the normalized radial flux coordinate, ρ . At the magnetic axis $\rho = 0$. At the outermost closed flux

Fig. 3. Coarse ENERGY code flow chart.

surface (limiter flux surface or separatrix) $\rho = 1$. The flux surfaces are obtained from an in-house full MHD equilibrium code called EFIT³ which assumes toroidal symmetry. The ENERGY code assumes that parameters are constant on a flux surface. As one of the ENERGY code inputs, the timeslice based EFIT mapping files are stored in a designated D3PHYS subdirectory. To ensure data traceability the EFIT code input parameters are also stored.

The ENERGY code uses least squares minimization techniques to fit a profile to any combination of local or line integrated data. If a cubic spline fit is specified,

ENERGY code output includes the number of knots, the knot locations in ρ space, and the profile value and estimated error at each knot. A parabolic fit has the form $\text{EDGE} + (\text{CENTER} - \text{EDGE})(1 - \rho^\gamma)^\alpha$. The central and edge profile values and the α and γ exponents with their error estimates are outputs when a parabolic fit is specified. Other ENERGY code outputs common to all profiles include the ENERGY code mode number, the boundary conditions of the fit, and a measure of the quality of the fit.

Each type of profile is treated as a separate subexperiment with its own D3PHYS subdirectory, YOKA file format, and S1032 dataset definition. The ENERGY code is in its own D3PHYS subdirectory. The source of input data for the ENERGY code as compared to other analysis codes is the major difference between the implementation of the profile subexperiments and others. Whereas other analysis codes use data directly from the DIII-D raw data archive, the ENERGY code uses data from the other subexperiment analysis codes.

Unlike other analysis codes, the ENERGY code does not create a YOKA file which can be submitted directly to the YOKA databases. Instead a separate program uses the ENERGY code output file to create separate YOKA files for each profile. This intermediate program checks that each experimental data point input to the ENERGY code matches a value in a YOKA dataset and includes a pointer to that dataset parameter in the profile YOKA file. Figure 1, also referred to in Section I, shows a simplified path of information flow for electron density profile information derived from Thomson scattering and CO_2 interferometer data.

Figure 4 is an example of an electron density and electron temperature profile for DIII-D discharge 56073 at 1900 ms during ECH heating. At this timeslice the plasma is in L-mode just prior to an H-mode transition. Each profile is fitted with a four knot cubic tension spline. Sixteen points from the Thomson scattering diagnostic and one chord from the CO₂ interferometer system were used as input for the electron density profile. The electron temperature profile was derived from sixteen Thomson scattering points only.

Fig. 4. Electron density and temperature profiles for DIII-D discharge 56373 at 1900 ms.

IV. FUTURE PLANS

The near future calls for adding ion temperature, radiated power, rotational velocity, and Z_{eff} profiles to the YOKA databases. An interactive code to display and manipulate profile plots is under development.

Further work will use the YOKA profile information as input to transport codes to calculate transport coefficients. A transport dataset will be an additional level of the DIII-D YOKA databases.

The S1032 database management system supports high level language calls to access database information directly from FORTRAN. This feature is used by the code which produces the profile YOKA files. In the future such an interface can allow the ENERGY code to read directly YOKA database data.

V. SUMMARY

Profile information is being integrated into the centralized physics analysis databases for the DIII-D tokamak fusion research experiment. The in-house developed ENERGY code uses cubic tension spline fitting or parabolic fitting to calculate profiles derived from database diagnostic data. The DIII-D database architecture is meeting the design goals of flexibility, automation, and ensuring data integrity and self-consistency. The databases are an indispensable tool to manage vast amounts of data to address physics issues concerning plasma transport, confinement, and stability.

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