Database Structures and Interfaces for W7-X

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Abstract
The W7-X Experiment of the IPP, under construction in Greifswald Germany, is designed to operate in a quasi-steady-state scenario. The database structures and interfaces used for discharge description and execution have to reflect this continuous mode of operation.
In close collaboration between the control group of W7-X and the data acquisition group a combined design of the data structures used for describing the configuration and the operation of the experiment was developed.
To guarantee access to this information from all participating stations a TCP/IP portal and a proxy server were developed. This portal enables especially the VxWorks real-time operating systems of the control stations to access the information in the object-oriented database.
The database schema includes now a more functional description of the experiment and gives the physicists a more simplified view of the necessary definitions of operational parameters.
The scheduling of the long discharges of W7-X will be done by predefining operational parameters in segments and scenarios, where a scenario is a fixed sequence of segments with a common physical background. To hide the specialized information contained in the basic parameters from the experiment leader or physicist an abstraction layer was introduced that only shows physically interesting information. An executable segment will be generated after verifying the consistency of the high-level parameters by using a transformation function for every basic parameter needed.
Since the database contains all configurations and discharge definitions necessary to operate the experiment, it is very important to give the user a tool to manipulate this information in an intuitive way. A special editor (ConfiX) was designed and implemented for this task. At the moment the basic functionality for dealing with all kind of objects in the database is available. Future releases will extend the functionality to defining and editing configurations, segments and scenarios with task specific versions.

Keywords:
Database, fusion experiment, steady-state operation

Introduction

The next generation of the IPP's advanced stellarator devices with superconducting coils (W7-X) is at the moment under construction in Greifswald, Germany. The main goal of the design is to demonstrate the principle reactor capability of the stellarators in steady-state mode of operation. But W7-X is still an experimental device to investigate the physical properties of plasmas and find satisfying operational regions for high particle confinements. The hardware components as well as the heating systems are designed to handle discharges in the order of 30 minutes.

To operate the device over such long discharge periods special requirements have to be taken into consideration by the control and data acquisition system. During one discharge there is no possibility to interact manually with the control system, except for emergency reasons. This means the whole process of device control and component setup has to be planned in advance and followed by the control system. Since the physical objectives may likely change during one long discharge for numerous times and the control system has to change the behavior of the components on a frequent basis, the experimental runs are divided in phases called segments. Each segment describes the state and the behavior of the technical and diagnostic components during the duration of the segment. The sequence of segments describes the whole experimental program. To simplify the generation of programs sequences of segments that often recur or reflect a special physical objective are grouped to so-called scenarios. In a scenario the sequence of segments is fixed. Every segment ends by a condition and if successful the control system switches to the next planned segment. If a segment fails, the control system may divert to another scenario or go to an idle state.

Data acquisition in very long-pulse mode or steady-state operation is necessarily a continuous task. Data must be read out from devices continuously and transferred to the archive guaranteeing no loss of data. Since the requirements for signal measuring may change from segment to segment the data acquisition systems have to react on segment changes, too.

All information regarding configuration of the components as well as all operational parameters (segments, scenarios, programs) necessary to run the experiment are kept in an object-oriented database [1] [2].

In this paper we describe some of the structures and interfaces in the database as well as the applications needed to access and modify the content of the database.

TCP/IP Portal to the database

The W7-X control system consists of a slow control branch built on PLCs for control of slow processes and operational management and a fast control system for forward and feedback control of plasma related components [3] [4]. The fast control stations use the real time operating system VxWorks and usually work on a 1 ms duty cycle. They are responsible for execution of the segment information defined in the experiment run. All segment information is extracted from the database in advance of a discharge and prepared for execution.

As object-oriented database we use Objectivity where access to the database is implemented by a client-server model. The client code of the database resides on the workstation side and hides all the interaction with the server. For VxWorks no client software is available; we therefore had to develop an interface based on TCP/IP sockets, which are generally available on the VxWorks system. Figure 1 shows the outline of the communication between the database and the fast control stations. Two different proxies are available for read and write access. This separation is necessary since only one federation can be accessed in Objectivity by an application at the same time. The servers are written in the java language and use on the database side the already available data access layer needed for all other applications. The clients in the VxWorks system are programmed in C and C++. A set of client-side interface routines are defined for recursive access to the objects in the database. Since the object structure is highly hierarchical with many referenced objects there is a special routine to resolve the references of the objects and retrieve the objects one at a time. In addition to specifying the object a selection of attributes can be specified in the call for objects. Serialization of data is done by a proprietary algorithm.

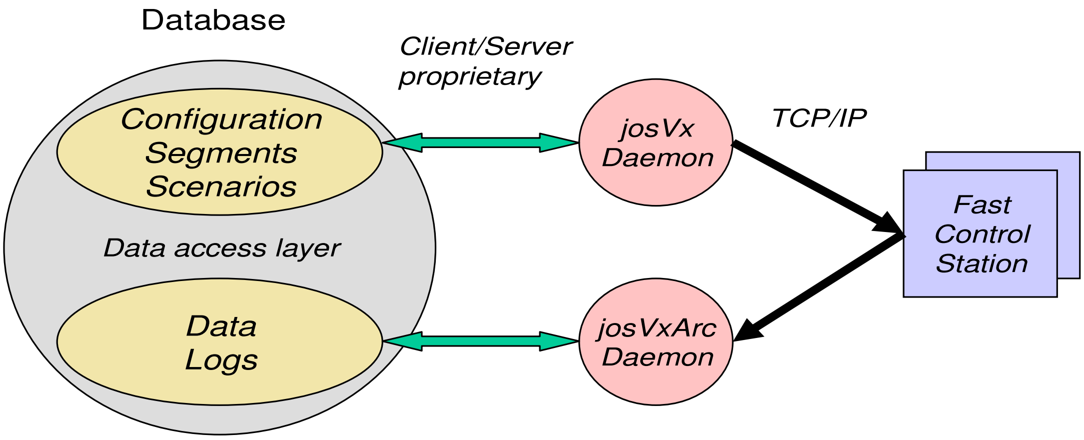

Figure 1: Fast control stations access the database through server proxies and the TCP/IP protocol. Two different daemons for read and write access are needed.

This approach is now in use for over a year and proved very successful.
The problem in Objectivity to access two different federations at the same time is also present in other applications. In the data acquisition application for example data has to be written into the archive and at the same time configuration and segment information has to be read from the configuration database. To solve this problem the same approach was chosen. Since the data has to be written fast and immediate, the read access was implemented via a TCP/IP Server. In this case the interface is a subset of the data access layer already available and written in java.

High-Level Parameters

The control system of W7-X has a hierarchical structure with the central control system on top and a large number of component subsystems at the bottom. Each component unit fulfills a special technical or physical task, like a heating system or a diagnostic subsystem. The components are again of hierarchical structure and consist of different control and data acquisition stations that work together. As shown in Figure 2 the structure of the control system is represented in the database by the respective hierarchy of project and group descriptors. The project descriptor represents the central control system of a project and stores all information necessary to operate the central system. The W7-X experiment is for example a project, but any independent system in the laboratory or any test system can likewise be represented by a project. The group descriptors describe the various components and the contained control and data acquisition stations and again contain all information necessary to operate the group. A group may also be operated independently from the project. Groups and projects are controlled via an interactive application (XControl) [5].
The segment descriptors follow the same hierarchy. The level of detail in a segment descriptor is naturally very high. Every parameter down to the lowest level in a module has to be specified and declared. This is principally necessary but not what an experimentalist and physicist wants to care about. They usually want to specify the behavior and state of the plasma and the machine in a more physical aspect. The hierarchy of the segment description allows the introduction of a new abstraction layer for the parameters. In every project and group descriptor a new entry for “high-level parameters” was included. These high-level parameters can be anything technically or physically meaningful like for example the heating

power needed for a special segment or the density of the gas etc. Nevertheless needs every control or data acquisition station the complete low-level parameter set to operate correctly. Therefore the high-level parameters must be transformed into low-level parameters. This is done via a set of transfer functions additionally specified in the project and group descriptors.

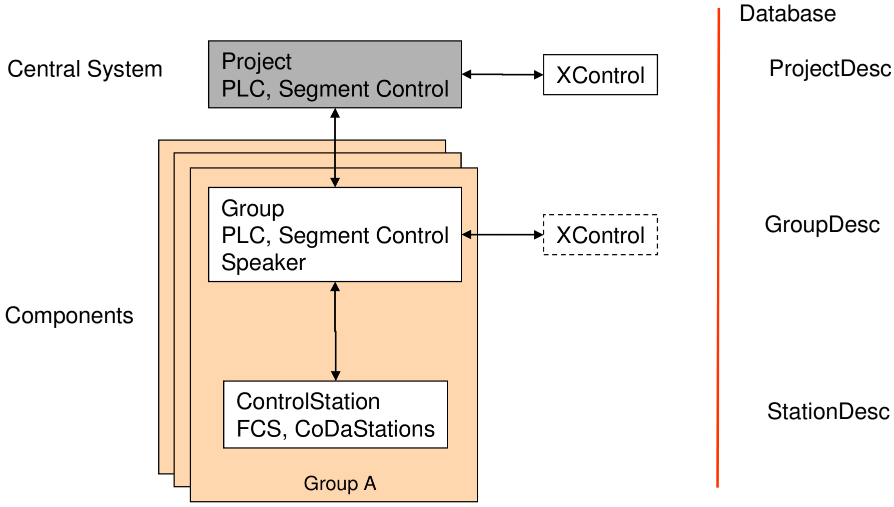

Figure 2: The control system of W7-X has a hierarchical structure with the central control system on top and a large number of components at the bottom. This hierarchy is reflected by a respective structure in the database.

The structure of these high-level parameters and their corresponding descriptors is given in Figure 3. Each project and group descriptor contains an array of parameter descriptors. Parameter descriptors can be of type simple value (float, double, integer etc) or of type parameter detail descriptor. The detail descriptors are used on one hand to group parameter descriptors (type sequence) or to allow the selection of different representations of the same items (type choice). An example for a choice would be the definition for the magnetic field. In one representation all currents for the coils can be given directly while in another representation the setting of currents would be done according to the designated magnetic field values. The descriptors of the simple values also contain information on the limits as well as the allowed

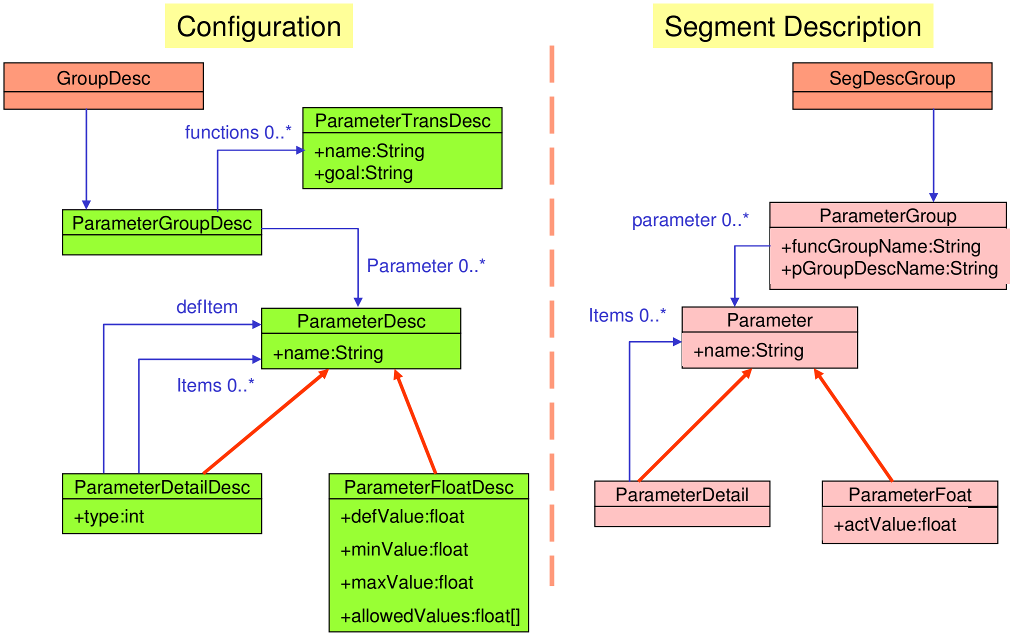

Figure 3: Structure of the high level parameter descriptors and the corresponding parameters in the segments.

values.
The segment descriptors for the high-level parameters have the same structure as in the project and group descriptors except that only one selected choice is allowed. For each low-level parameter a transfer function has to be declared that calculates from all high-level parameters in a sequence or choice the corresponding value. These functions can be very simple like a one-to-one function or highly complex like calculating coil currents from magnetic field values.

Editors for database structures

W7-X is a large experiment and consists of a multitude of technical components and diagnostic systems. Each of these components needs to be controlled by the central control system or take part in the data acquisition process. In both cases a very detailed description on the devices or modules to handle are essential. As already mentioned all the information on components and their subsystems is available in an object-oriented database. In addition to this more static configuration data the database also contains the data on segments and scenarios that are needed for controlling the discharge. All this information that is manifold and very detailed has to be prepared in advance of an experimental run. It is therefore very important for the acceptance of the system to have tools that support user-specific simplified views and editing capabilities.
There are different kind of users, the technical and scientific staff with a very good knowledge on the system internals, the experiment leader or scientist in charge that is only interested in physical questions and setups and the technicians and physicists responsible for a subsystem, that have to set their modules for the discharge. All have different needs on the level of detail and the amount of data to access from the database.
At the moment an editor (ConfiX) for all objects in the database is provided [6][7]. It does not distinguish between different kinds of objects and is mainly planned to be used by the control and data acquisition group. The functionality of the editor now includes a login procedure to control the user access rights on objects as well as various kinds of object states that have to be controlled. The segments and scenarios for example pass through various states until they are marked for execution. And once they have been run successfully they have to be marked

as unchangeable. In this manner a complete record of successfully run segments will be available. One important function will be the saving of objects in the segment descriptions. The object structure is hierarchical and the trees of objects can be rather deep. Objects can be referenced in different places in many different objects. A save on a modified object should of course only influence the direct parents in the tree and not any other tree or branch. The save function has to investigate the tree and make copies of all objects that are not allowed to be modified. This function is rather complex and work on the implementation is still in progress. In addition to this general editor a set of specialized editors is planned which will simplify the work with the database. These specialized editors are intended to be used by the general user of W7-X. The following is a preliminary list of editors planned for this purpose.

1. Configuration
    - Project Descriptor
    - Group Descriptor
    - CoDaStation Descriptor (data acquisition stations)
    - Fast Control Station Descriptor (control stations)

2. Experiment Control
    - Segments
    - Scenarios
    - Programs

3. General
    - Global Tables
    - Users and Groups

These editors only deal with special kind of objects and have a detailed knowledge on every object type. They will guide the user through the process of generating new objects and gather the information that is necessary to fulfill this task. Help will be provided on classes and objects that can be used for relations. Segments can be created from scratch by defining a root object or by copying an already existing segment and reusing all referenced objects or by generating a segment from the configuration data. The scenarios editor will have to deal with time lines and sequences of segments. Desirable is a graphical editor for time traces of elements specified in the high-level parameters of project or group descriptors. Fragmentation of scenarios into segments can be accomplished automatically on recognizable changes or by interaction of the user.

The specialized editors are implemented using new web technologies. The model view controller (MVC) design pattern strictly separates the view on a Web browser from the controller and the model in a servlet container. The model interface is the same for all editors and connects to the object-oriented database access layer. In a further extension the model interface could also be provided as web service or an enterprise bean. By using the Web browser for these applications no special installations on the client side are necessary and the tasks can be performed from any workstation. Performance seems sufficient on the intranet and is also addressed by using display components that are AJAX capable.

The implementation of these editors was started at the beginning of 2007 and is still in progress.

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