XAL-BASED APPLICATIONS AND ONLINE MODEL FOR LCLS*

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Abstract

XAL [1-3], a high-level accelerator application framework originally developed at the Spallation Neutron Source (SNS), Oak Ridge National Laboratory, has been adapted by the Linac Coherent Light Source (LCLS) project. The work includes proper relational database schema modification to better suit XAL configuration data requirement, addition of new device types for LCLS online modeling purpose, longitudinal coordinate system change to better represent the LCLS electron beam rather than proton or ion beam in the original SNS XAL design, intensively benchmark with MAD and present SLC modeling system for the online model, and various new features to the XAL framework. Storing online model data in a relational database and providing universal access methods for other applications is also described here.

INTRODUCTION

XAL provides the following features: a hierarchical view of an accelerator, physics modeling tool, a common look-and-feel graphical user interface (GUI), tools for easy access of EPICS [4] Channel Access (CA) protocol and database, and many other utility packages. In order to take advantage of the XAL accelerator hierarchy, one has to prepare all necessary data in the XAL format.

The XAL online model at SLAC has been improved to accurately model an electron beam accelerator, several miscalculations of physics parameters have been fixed and changes were made to accommodate the different longitudinal coordinate system.

The SLAC implementation of the XAL model was also required to be compatible with the existing Stanford Linear Collider (SLC) online model system so that existing applications would continue to work. The SLC model did not run in real time, but on demand so a database infrastructure and access system was setup for the XAL model data.

DATABASE SETUP

There are two major database schemas set for XAL and its model. The first one is for XAL input configuration and the second one is for storing XAL model run output data for other applications to pick up.

XAL Configuration

The XAL data structure is based on hierarchical view of an accelerator, whereas most modern data storage uses relational databases. A mapping between the XAL data structure and database is needed. Usually a database query along with such a mapping is performed to create an XAL formatted XML file. This XML file is then served as the base configuration file for all XAL needs. The data extracted from database are mainly from two views: *elements* and *symbols*. The elements view contains information for each hardware device such as physics name and EPICS device name. Data for the MAD optics design lattices are saved in the symbols view. These views were modified to add XAL specific entries such as beam line sequence and distance from the start of the sequence. Figs. 1 and 2 show screen snapshots for an XAL database browsing utility. The left panel shows the schema, the middle panel shows the tables and views for the selected schema and the right panel shows part of the columns in the elements and symbols views.

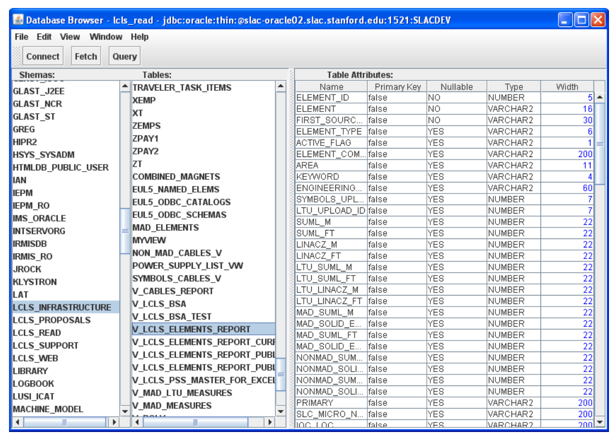

Figure 1: LCLS elements view from Oracle database.

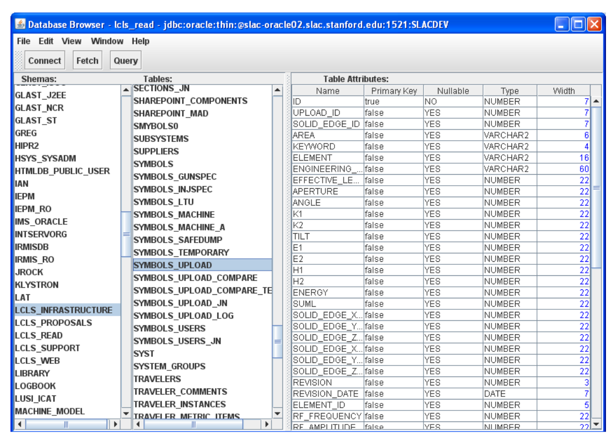

Figure 2: LCLS symbols view from Oracle database.

*Work supported in part by the DOE Contract DE-AC02-76-SF00515. This work was performed in support of the LCLS project at SLAC.
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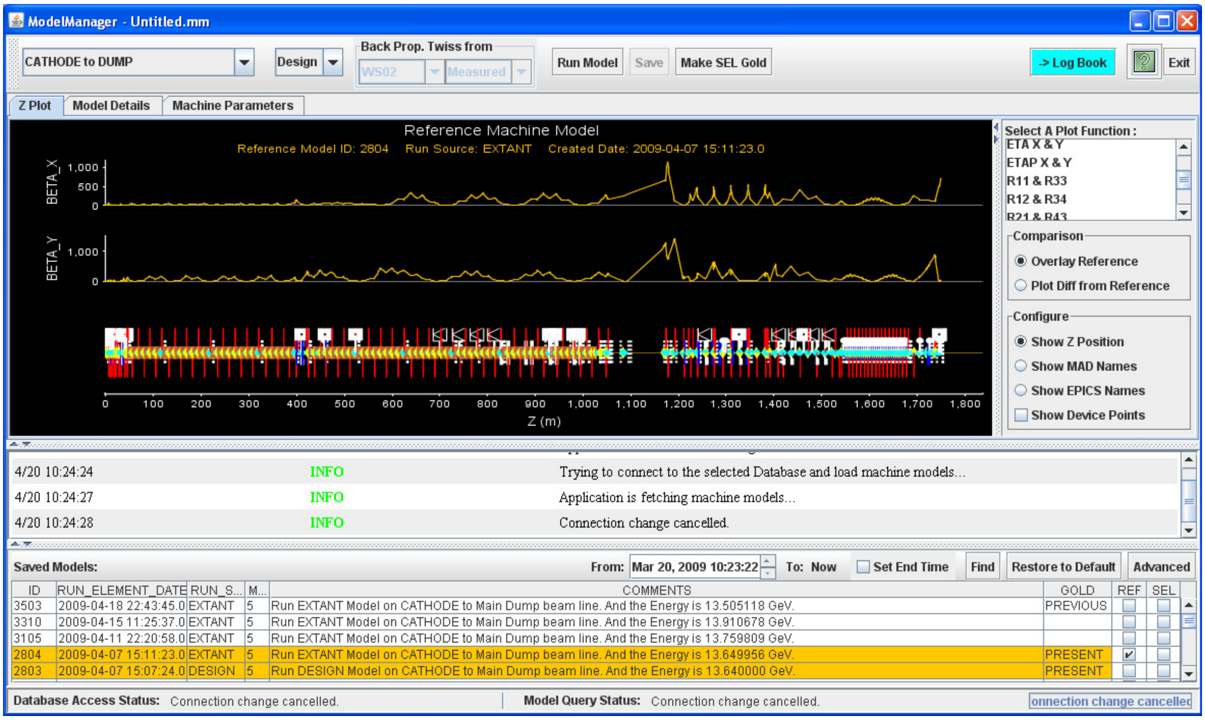

Figure 3: Model Manager application for running, viewing and saving the XAL. The top tool bar is for running the model, the middle panel is for data display and the bottom panel is for selecting available models from database. The data panel shows an example of extant machine β-function over the entire LCLS.

The database to XAL data structure mapping within our present schema is still being completed in order to automate some integrated field to field conversion factors.

XAL Model Data

The XAL online model data is uploaded to an Oracle database [5] for other applications to pick up. An easy interface, Accelerator Integrated Data Access (AIDA) [6], provides a universal way to access the model data stored in the database. Currently, there are four beam-line modes, 'Cathode to Main Dump', 'Cathode to Gun Spectrometer', 'Cathode to 135-MeV Spectrum Dump' and 'Cathode to 52SL2'. Each beam line may be modeled using design parameters or extant values for the devices as the data source. For each beam-line and data source, a Gold tag is introduced to indicate the default model to be used by other applications for that beam-line and data source combination.

ONLINE MODEL

The XAL online model [7] was first written for a spallation neutron source with H^- or proton beam. The transfer map computation was based on TRACE 3-D [8] algorithm. On the other hand, LCLS is a light source with electron beam and unique devices such as undulators. The LCLS electron beam velocity is highly relativistic; therefore, the longitudinal coordinate has to be in the reference particle frame.

Transfer Map

The LCLS design and the SLC model system are based on MAD optics calculations, so any new model system should follow the same calculations. Transfer matrices for the following modeling elements in XAL were modified based on the MAD algorithm [9]:

- Bend dipole
- RF accelerating gap
- Solenoid magnet
- Drift space

These new maps were also added:

- SLAC RF cavity
- Undulator segment with vertical focusing and no energy loss.

Particular attention was paid to handling the edge effects for bend dipoles and RF cavity/accelerating gaps when these elements are split within the program. After our modifications the transfer matrices computed by XAL and MAD are nearly identical.

Twiss Parameters

Together with the correct transfer matrix computation, the Twiss parameters are now computed with proper relativistic correction.

Benchmark Comparison

After the transfer map modifications described above, the XAL model was carefully compared with the MAD model in term of energy calculation, R-matrix and other physics parameters. Initially the Twiss parameters did not agree well enough, so we took the R matrices from XAL, computed Twiss parameters in a Matlab script outside XAL and loaded them back to XAL model. We have now modified the XAL Twiss parameter calculation so that the entire process is handled by the new LCLS XAL model.

Fig.4 shows a comparison between this version of XAL model and MAD throughout the entire LCLS main beam-line, from gun to undulator. There is slight difference near the largest β-function (>500 m). After careful study, we have confidence that the XAL model does the right calculation.

Figure 4: XAL model versus MAD model.

Figure 4: β-function comparison between MAD and XAL model. The plots show horizontal (top) and vertical (bottom) β-function along the entire LCLS. Red curves from MAD are overlaid on blue ones from XAL.

Chicane Magnets

Typically, the XAL online model assumes that the reference trajectory always follows the design bend angle while passing through a chicane magnet. For LCLS, the energy variation can be quite large and, therefore, this assumption is no longer valid for the live machine. The reference angles are therefore dynamically adjusted according to the ratio of the live field to the design field.

Acceleration Structure

At present, the LCLS control system does not provide EPICS CA signals for most of its RF cavities. A separate routine is written to query the old SLC control system for the klystron settings via AIDA. This routine calculates the phases and amplitudes for all the accelerating cavities based on klystron information as well as five well-defined reference energy points. The result is inserted into the XAL model.

Reference Point Twiss Back Propagation

The beam-line tracking that starts at the cathode of the 6 MeV gun in the LCLS suffers from inaccurate modeling of the space charge effects and would result in unrealistic Twiss parameters being propagated downstream. A more accurate method that we have adopted for the online modeling is to take the measured Twiss parameters at a point far enough downstream for space charge effects to disappear and then back propagate this beam to the cathode. This beam is then propagated down the length of the machine to give an accurate representation of the Twiss parameters in the extant lattice. The back propagation of this beam through the solenoid at the low-energy gun requires that solenoids are treated as drift spaces in this procedure, since the conventional Twiss parameters we use do not include coupling terms that a solenoid would introduce. This has not been a problem for us since the optics of interest during machine operation are all downstream of the gun solenoid.

APPLICATIONS

The LCLS XAL model is now the primary online model for LCLS operation. Two XAL-based Java applications are the mainstays of control room operation, the Orbit Display and the Model Manager GUI (Fig. 3). The XAL model Application Program Interface (API) means that online model data is now also used by a host of other programs in the control room including the Linac Energy Management program (LEM) and a number of other Matlab scripts used for emittance measurement and beta matching. The accessibility of online XAL model data to Matlab applications has allowed LCLS to rapidly prototype many new applications. Model data can also be exported to spreadsheet files for offline analysis. Future plans include enhancements to the database schemas and further optimization of the model run performance time.

ACKNOWLEDGEMENTS

The authors would like to thank the LCLS Physics, Controls, Database and Operation groups for their great efforts in providing us various hardware and software support, as well as finding errors. All the other members in the SLAC High Level Application group deserve much credit for their valuable suggestions and help.

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