XAL APPLICATIONS DEVELOPMENT FOR CSNS TRANSPORT LINES

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Abstract

XAL is an application programming framework initially developed at the Spallation Neutron Source (SNS). It has been employed as a part of control system via connection to EPICS to provide application programs for beam commissioning at the China Spallation Neutron Source (CSNS). Several XAL-based applications have been developed for Beam Transport line at CSNS and successfully applied in the MEBT and DTL-1 beam commissioning. These applications will be discussed in this paper.

INTRODUCTION

The CSNS, including of proton accelerator, target station and neutron spectrometers, is a large facility to produce neutron by 1.6 GeV protons colliding a target of heavy metal [1]. The accelerator is mainly composed of a linac with a modest but upgradable energy and a rapid cycling synchrotron (RCS) of the fixed energy at 1.6 GeV. The installation and beam commissioning of the front end of linac, medium energy beam transport line (MEBT) and first section of the drift tube linac (DTL-1) was finished. The beam commissioning of DTL2-4 and the linac to ring beam transport line (LRBT) is upcoming this September.

XAL [2] is a Java framework for developing accelerator physics applications for the commissioning and operation of the SNS. It was used and developed by many accelerator laboratories, e.g. SNS, SLAC, FRIB, LANL, etc. XAL was designed to be extensible and has evolved to support ongoing accelerator operations. CSNS and SNS have lots of similarities in both physics and hardware. Therefore, the XAL was selected as the tool for beam commissioning of CSNS accelerator.

Some of the applications in XAL can be directly used, such as general applications like SCNAD-1D, SCNAD-2D, some physical applications like orbit correction, MPX [3], etc. However, more XAL applications can only be transplanted after appropriate modifications for the reason of the differences of hardware devices or data formats. For example, The PASTA application [4], which is for the adjustment of the phase and amplitude of the cavity, has been changed a lot for CSNS. The reason is that the BPMs were used in SNS for the phase scanning while FCT were used in CSNS. Meanwhile, a number of new XAL-based applications have also been developed, some of which are described as below.

APPLICATIONS WITH DATABASE

Due to the advantages of data management and data query, database is used by more and more accelerator laboratories for the management of the data with large volume. According to their own consideration, different database management system was used in different laboratories. The Oracle is used in SNS, the J-PARC choose PostgreSQL, FRIB use MYSQL, and in our case we choose the MYSQL database.

Database related applications are widely used in the beam commissioning. Applications in XAL, like Score [5], PVlogger choose the database to logger signal and restore machine. Some examples of physical applications used database in CSNS will be presented.

Model Management

Model management is one of the most important applications in the beam commissioning, which is responsible for the management of the lattice model, model storage, lattice calculation, etc.

Based on the lattice and model service architecture diagram [6], the client application was developed to manage models. Fig 1 is the operation interface, which provides three model sources: database, local file, and the XML file. The models will be displayed according to the serial number, model name, date, energy, and comments when-connecting to the database. The model can be founded by filtering the letter in the model table or searching by time span. The device information including position, type, the magnet field and cavity field will be displayed in the table below when a model is chosen. We can put the stored values to control system for the selected magnets or certain types of magnets. The lattice calculation for the current model can be carried out and the results also can be displayed with graphics. This function has been embedded in the MPX application.

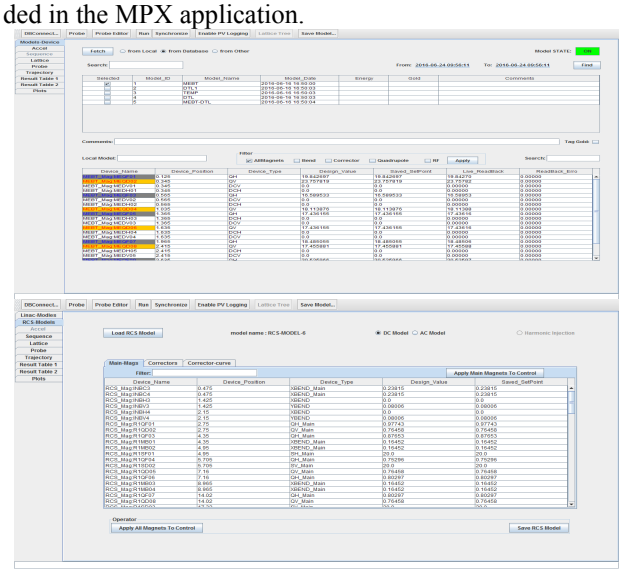

Figure 1: Model management application (The above is for Linac, the below is for RCS).

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The design above only meets the requirements of the model management for linac. Due to the particularity and complexity of the RCS ring, the mode management for RCS ring was redesigned. Fig 1 (below) shows the design of RCS model management.

The information of a corrector in RCS is an array of 21 numbers which stand for 21 energy points. So the correctors should be separated from the other magnets. The DC mode and AC mode are also different when the stored values were applied to the control system. In addition, harmonic injection of the magnets' power supplies has also been considered.

Score Application

Accelerators are inherently complicated devices consisting of multiple systems, such as magnet, power supply, control, vacuum and so on. Efficiently managing the proper device settings is an important part of operations and beam study. We need one application to save machine settings, compare live values with save values and restore saved values. A program called SCORE (Save Compare and Restore) was developed at the SNS for this purpose. However, Oracle database management system was used in SNS, so we cannot use it directly. We modify the interface which is associated with the Oracle. The database schema also made some changes. Fig 2 is a test of the MEBT and DTL sequence with the information of magnets, power supplies, RF cavities and beam diagnostics instruments.

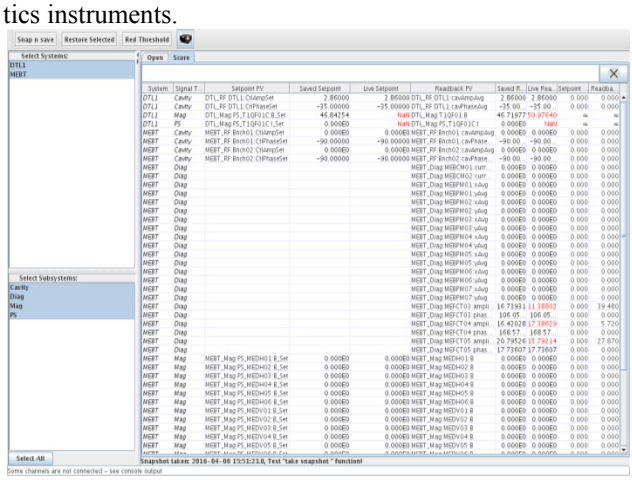

Figure 2: Score application.

Magnet Manager Application

CSNS linac and RCS contain more than 400 dipole, quadrupole, sextupole, octupole, corrector and kicker. We created magnet database to store magnet installation information, magnetization curve data and fit results [7]. This database also can be used by records creating application to create the records for the soft IOC database easily. A magnet database manage application was developed in JavaFX to upload and fit magnetization curves data. Fig 3 is one of the example shows one magnet measurement result.

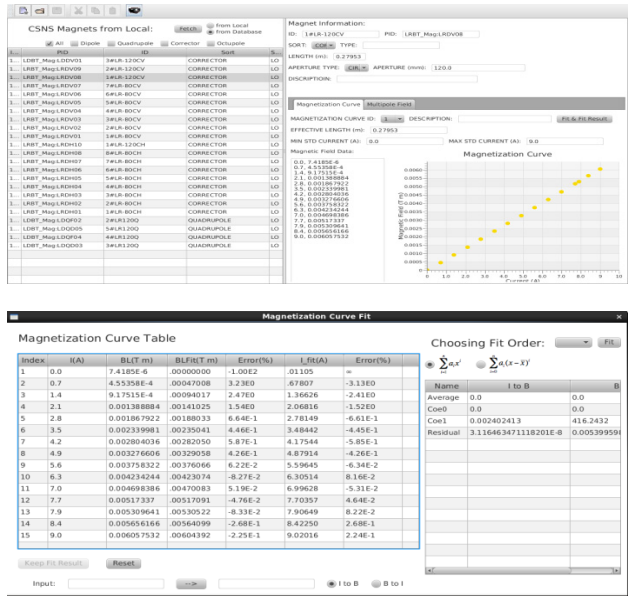

Figure 3: Magnet database manager interface and magnetization curve polynomial fitting interface.

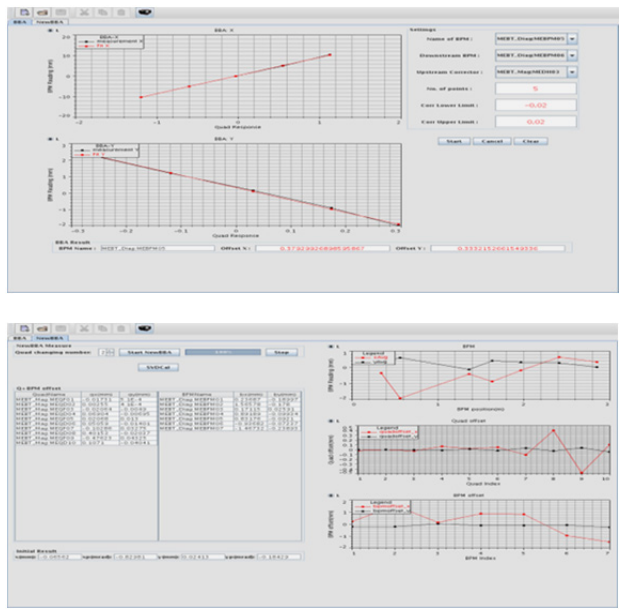

Figure 4: The operation interface of BBA application (he above is first method, the below is second method).

APPLICATIONS WITHOUT DATABASE

BBA Application

The control of beam loss is quite strict for the reason of high power proton. Orbit correction should be done first to decreasing the beam loss. Unfortunately, it can't reach the expected purpose with big errors. One of the strongest error sources of beam orbit distortion is random misalignments of quads and BPMs. The most advanced approach for distorted beam orbit fine correction is the BBA technique. Two kinds of BBA approaches were applied in CSNS. The first is a tradition approach, which can give the value of BPM offset conveniently and accurately. However, scanning over all BPMs is time consuming

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procedure. The second modification BBA algorithm looked more promising, which can get the quad and BPM transverse misalignments simultaneously. This algorithm is based on difference orbit multiple measurements. Meanwhile, the liner optics between all beam line elements must be known. Fig 4 is the operation interface of BBA application, which gives the offsets of all quads and BPMs respectively.

Double Slit Emittance Analysis

The emittance is one of the most important transverse parameters in linear accelerators or transfer lines. Multiple wire scanners (WS) and double slit were installed in CSNS/MEBT to measure the emittance. The first method is based on wire scanner profile measurement at three or more locations along the beam line. The raw data of WS with modification format can be applied in xal wireanalysis program [8] to obtain the exact emittance. However the data format of double slit is more complicated. A new application is encoded, and embedded into the wireanalysis panel. The two small phase ellipse in Fig 5 is calculated by statistics and Gaussian fitting methods respectively. The data used in the calculations are experimentally measured and not processed, which are different from the data after fitting according to the color in SNS. In addition, the influence of the selection of threshold on the calculation results has also been considered [9].

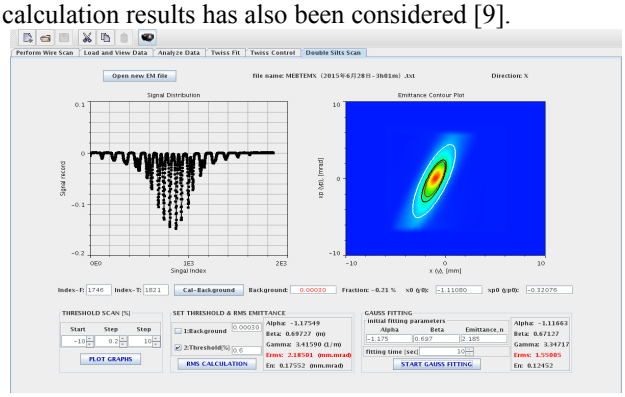

Figure 5: The emittance analysis application.

Fudge Factor Measurement Application

Due to all kinds of errors, the real optics will be different from the design one. The fudge factor measurement application was developed to deal with this issue and improve the optics of CSNS transport line. The fudge factor AF, used to describe the correction of quadrupole strength to restore the optics, which is calculated by fitting the measured response matrix to the model response matrix. An XAL optimization package was employed to do the fitting. Fig 6 is the GUI of the Fudge factor measurement tool which shows one example of one quad with given error.

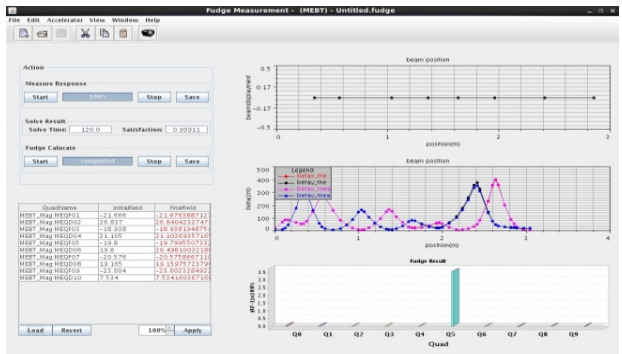

Figure 6: Fudge factor measurement application.

SUMMARY

Based on the XAL framework, some applications were modified or written for CSNS and has been successfully used in the beam commissioning of CSNS linac and transfer lines. This paper discussed some applications with and without database.

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