

Online Model Server for the Jefferson Lab accelerator*

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Abstract

A beam physics model server (Art++) has been developed for the Jefferson Lab accelerator. This online model server is a redesign of the ARTEMIS model server [1]. The need arose from an impedance mismatch between the current requirements and ARTEMIS capabilities. The purpose of the model server is to grant access to both static (machine lattice parameters) and dynamic (actual machine settings) data using a single programming interface. A set of useful optics calculations (R-matrix, orbit fit, etc.) has also been implemented and can be invoked by clients via the model interface. Clients may also register their own dynamic models in the server. The server interacts with clients using the CDEV protocol and data integrity is guaranteed by a relational database (Oracle8i) accessed through a persistence layer. By providing a centralized repository for both data and optics calculations, the following benefits were achieved: optimal use of network consumption, software reuse, and ease of maintenance.

1 INTRODUCTION

The CEBAF accelerator is a 6 GeV, 5 pass, continuous beam electron recirculating linac [2]. The two superconducting linacs are joined head to tail by beam transport systems. The beam can be extracted during any of the five passes and delivered to three experimental halls. The purpose of Art++ is to provide an accurate and timely representation of the machine for high level applications such as the fast feedback system [3] or the automated beam steering system [4]. As such, Art++ serves as a central repository for beam physics calculations (twiss functions, R-matrix, trajectories, etc.) and facilitates access to the set of parameters characterizing any beam element. By centralizing the source of information and beam physics algorithms, we leverage beam physics expertise and our knowledge of machine parameters.

2 ARCHITECTURE

Art++ is a distributed system, utilizing CDEV [5] as its underlying protocol. The software architecture is object-oriented, written in C++, and is organized in modules as shown in figure 1. Each module is decoupled from the others and accessed only by means of a well defined interface. The core module encompasses the business logic pertinent

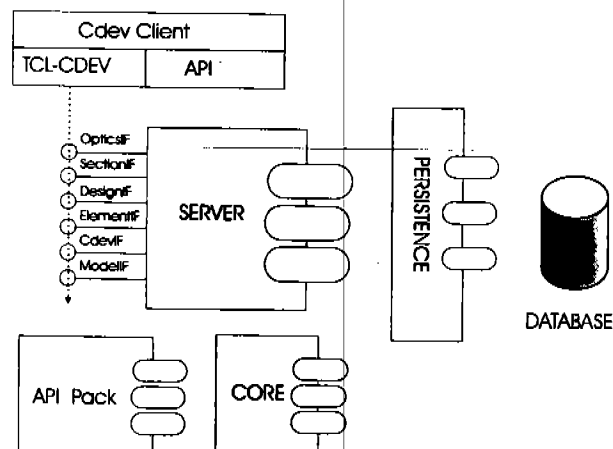


Figure 1: Art++ physical view.

to the modeling of the accelerator. The server module relies on CDEV protocol to interact with clients exposing a number of interfaces for the clients to act upon. The API Pack module contains a number of parser classes to interface with external data sources. The persistence layer provides database functionalities to the core module. Currently, the supported database mechanisms are relational database tables, implemented in Oracle, and flat files.

2.1 Core package

The core package encompasses all the classes directly related to the problem domain. The class hierarchy shown in figure 2 is closely matched to the real accelerator structure. A model class holds a set of beam segments; each segment contains a set of generic beam elements. More specialized versions of the beam element class embody optical concepts such as quadrupoles, dipoles, drift sections, etc.

The segmentation of the beam line is shown in figure 3. Points of segmentation fall naturally at the beginning of each beam transport section delineated by the separation or recombination parts.

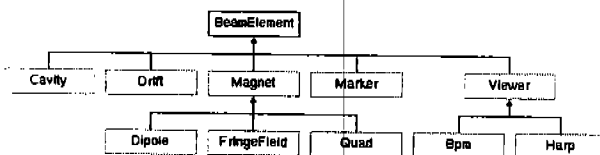


Figure 2: Art++ class hierarchy.

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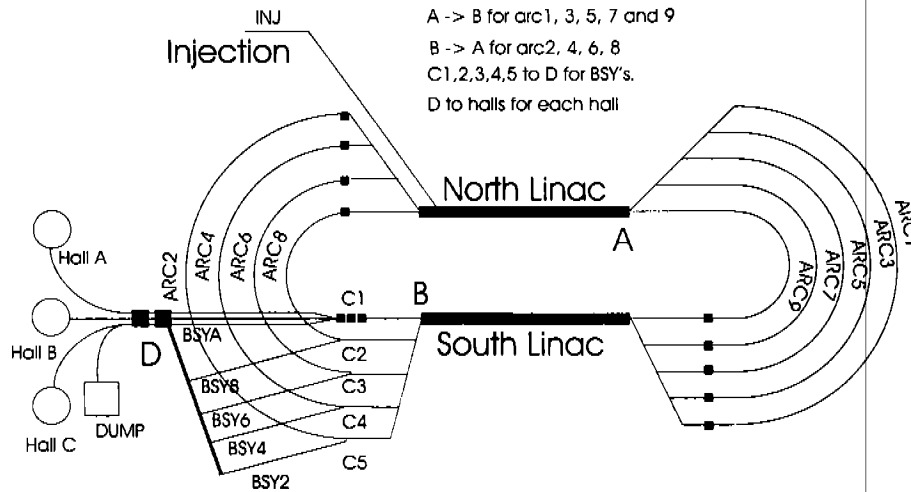


Figure 3: CEBAF accelerator lattice segmentation.

2.2 API Pack package.

Interfacing with external data sources is accomplished by the API Pack package. It contains various parser classes to read machine descriptions and currently supports only the Optim[6] and twiss input files. Its framework can easily be extended to deal with other formats. The accelerator lattice is specified by an xml [7] configuration file which describes the beamline segmentation. Here is a typical configuration file for a short stretch of the machine, namely the injector and the first arc:

```

<model>
<lattice name='CEBAF'>
<section name='INJ' energy='5.01268'>
<optfile>inj_nlp.opt</optfile>
<twissfile>inj_nlp.twiss</twissfile>
</section>
<section name='ARC1' energy='MMSARC1E'>
<optfile>arc1p.opt</optfile>
<twissfile>arc1p.twiss</twissfile>
</section>
</lattice>
<layout>
<pass number='1'>
<section>INJ </section>
<section>ARC1</section>
</pass>
</layout>
</model>

```

Each segment is defined by its name and corresponding Optim and twiss files that provide all the static parameters needed by the model. We will refer to this set of data as the "design" model in the rest of this paper.

2.3 Server package

The server package adapts the CDEV server interface to the internals of Art++. It retrieves incoming messages, dispatching them to relevant server methods and sending results back to the clients.

2.4 TCL-CDEV interface

Art++ can be queried via the TCL scripting language and TCL-CDEV extension [8]. The use of TCL scripting language facilitates rapid prototyping [9] of new applications. It can also be used for simple situations where performance is not a stringent requirement.

2.5 API

Alternatively, Art++ can be accessed via an API provided by a C compatible shared library. We chose not to make it a C++ library with exported classes because of the need to support legacy applications written in C. This API allows any user of the control system to write thin-client applications making full use of the model server. By utilizing CDEV as the underlying protocol, users can develop distributed applications with minimal effort.

2.6 Persistence layer

The role of the persistence layer [10] is to encapsulate access to the database, so that details about database table layout and corresponding SQL or OCI (Oracle Call Interface) query mechanisms need not be coded into the application. With the persistence layer in place the database can be re-organized and the data access routines tuned without any modification to the application itself. The persistence layer uses a data dictionary to allow mapping application objects to relational database tables and rows [11]. Although it might seem natural to use an object-oriented database to avoid such object-to-relational mapping, we decided the effort of translation was worthwhile because information stored in a relational database will be more accessible and easier to maintain. Information that needs to be updated often, such as beamline survey data or magnet field properties, can be maintained by simple scripts written by other staff.

3 BEAM PHYSICS COMPUTATIONS

Art++ provides availability to the following:

- Generation of first order matrices.
- Calculation of twiss parameters.
- Evaluation of transfer matrices at first order.
- Correct treatment of the acceleration process in the linac including adiabatic damping and cavity focussing effects.
- Determination of orbits.

All Art++ computations are carried out at first order. Transfer matrices are computed by using twiss parameters instead of the alternative approach that calculates the product of all the matrices. This procedure results in an $O(1)$ performance in transfer matrix evaluation.

4 ONLINE REALTIME MODEL

To establish an accurate view of the machine, it is necessary to track changes in the beamline in realtime. The dynamic parameters for each dipole, quadrupole and cavity are monitored. Whenever one such element changes, its local transfer matrix is recomputed and the twiss parameters recalculated by forward propagation from that point onward to the end of the segment. As in the case of the design model, the realtime model evaluates transfer matrices using twiss parameters.

5 HIGH LEVEL APPLICATIONS

Several high-level applications are using or being modified to use Art++:

- Autosteer [4] is a multi-pass orbit correction steering algorithm used at Jefferson Lab to steer the machine. Autosteer determines the optimal corrector settings to minimize beam displacement. It utilizes Art++ to retrieve transfer matrices between beam position monitors and correctors.
- Automatch [12] performs beam envelope matching between the transport segments. It requires knowledge of the twiss parameters for the filling sections. Art++ computes these twiss parameters in realtime for use by Automatch.
- The fast feedback control program [3] corrects the beam position and energy disturbances using a control loop based on a linear quadratic gaussian controller/estimator. Art++ will be utilized by the fast feedback system in its setup phase to retrieve twiss functions for various elements.

We plan to port all the high level applications to this new model server. Preliminary testing of the server was carried

out concurrently with the testing of Automatch. The first results show that the server behaves as expected. It exhibits a dramatic performance increase over Artemis, utilizing only a fraction of the model server CPU time (5 % versus 80 % for Artemis).

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