MODELING RHIC USING THE STANDARD MACHINE FORMAT ACCELERATOR DESCRIPTION*

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Abstract

The Standard Machine Format (SMF)[1][2] is a structured description of accelerator lattices which supports both the hierarchy of beam lines and generic lattice objects as well as those deviations (field errors, alignment errors, etc.) associated with each component of the as-installed machine. In this paper we discuss the use of SMF to describe the Relativistic Heavy Ion Collider (RHIC) as well as the ancillary data structures (such as field quality measurements) that are necessarily incorporated into the RHIC SMF model. Future applications of SMF are out-lined, including its use in the RHIC operational environment.

1 INTRODUCTION

The description of circular accelerator lattices has two major phases. In the design stage before and during construction, generic elements and beam lines are commonly used. In the latter phase of construction and on into operations the generic description is usually discarded in favor of a "flat" view of the machine where each component in the ring has its own characteristics such as magnetic field deviations or misalignment. In the flat view of the machine one can not easily recover the symmetry properties of the original design in case one wishes to investigate the lattice's basic properties anew. If in order to carry out these investigations one does then go back to the original design lattice, one often finds that essential details (unrelated to non-generic quantities such as field errors) have not been incorporated. The maintenance of an accurate generic description along with the detailed flat description becomes a quandary. The Standard Machine Format (SMF) [1][2] was created to unify these two phases of development in a single set of data structures. In this paper we discuss the use of SMF to manage the design and operation of the Relativistic Heavy Ion Collider (RHIC). We first discuss the definition of SMF, and then describe the particular ways in which the various RHIC data stores are incorporated.

2 SMF DATA STRUCTURES

The Standard Machine Format consists of four levels of description (classes):

1. Parameter
2. Generic Element
3. Line
4. Lattice

Parameters are names which are assigned specific values. *Generic Elements* are defined as structures having attributes appropriate to the accelerator object. For example, a bending magnet has length, strength, edge fields, etc. Each type of generic element incorporates specific attributes which are assigned values. Attributes may be assigned values using parameter names which subsequently take the parameters' values. New attributes can easily be added to the list. A *Line* is a structure composed of generic elements and other lines. A Line is a generic structure like the previous levels of description. Finally, *Lattice* is a sequential list of Lattice Elements which retains the memory of the hierarchical tree of lines contained in the lattice even while being a flat description. A Lattice Element is derived from one of the Generic Elements but contains in addition the deviations from its generic value of magnetic field strength, alignment, etc.

3 RHIC DATA STORES

Figure 1 provides a schematic view of the data stores and processes required to construct the RHIC SMF. The top level of the figure shows the basic data structures required, namely optics, name correlation, magnetic field and survey measurements. The RHIC accelerator physics group has responsibility for the optics design. This is maintained in an *Optics Model* [3] within a relational database. However, a complete model of RHIC also requires information about magnetic field and survey alignment data which are controlled and maintained by other groups within the RHIC organization. Consequently, the construction of the SMF requires the communication of the data from these other groups which must then be correlated with the basic optics model. Because magnets and other equipment to be installed in the accelerator have been named differently by the various groups, we have to resort to a *NameLookup* structure to resolve the correlation problem. Finally, the raw measurement data from the other groups must be processed before it can be incorporated into our lattice SMF model. We now discuss each of these component data stores in turn.

3.1 Optics Model and NameLookup

The lattice database at RHIC had its beginnings in the SSC Central Design Group. This database structure has been discussed previously [3], and we will not go into the details here. It should be sufficient to note that the optics description provided by the database is modeled after the Standard Input Format (SIF) [4] (incorporated into MAD and many other programs). The lattice database is used to maintain the design of the machine. From this hierarchical description a flat C structure is generated by a program using the *Self-describing Data Standard* (*SDS*)

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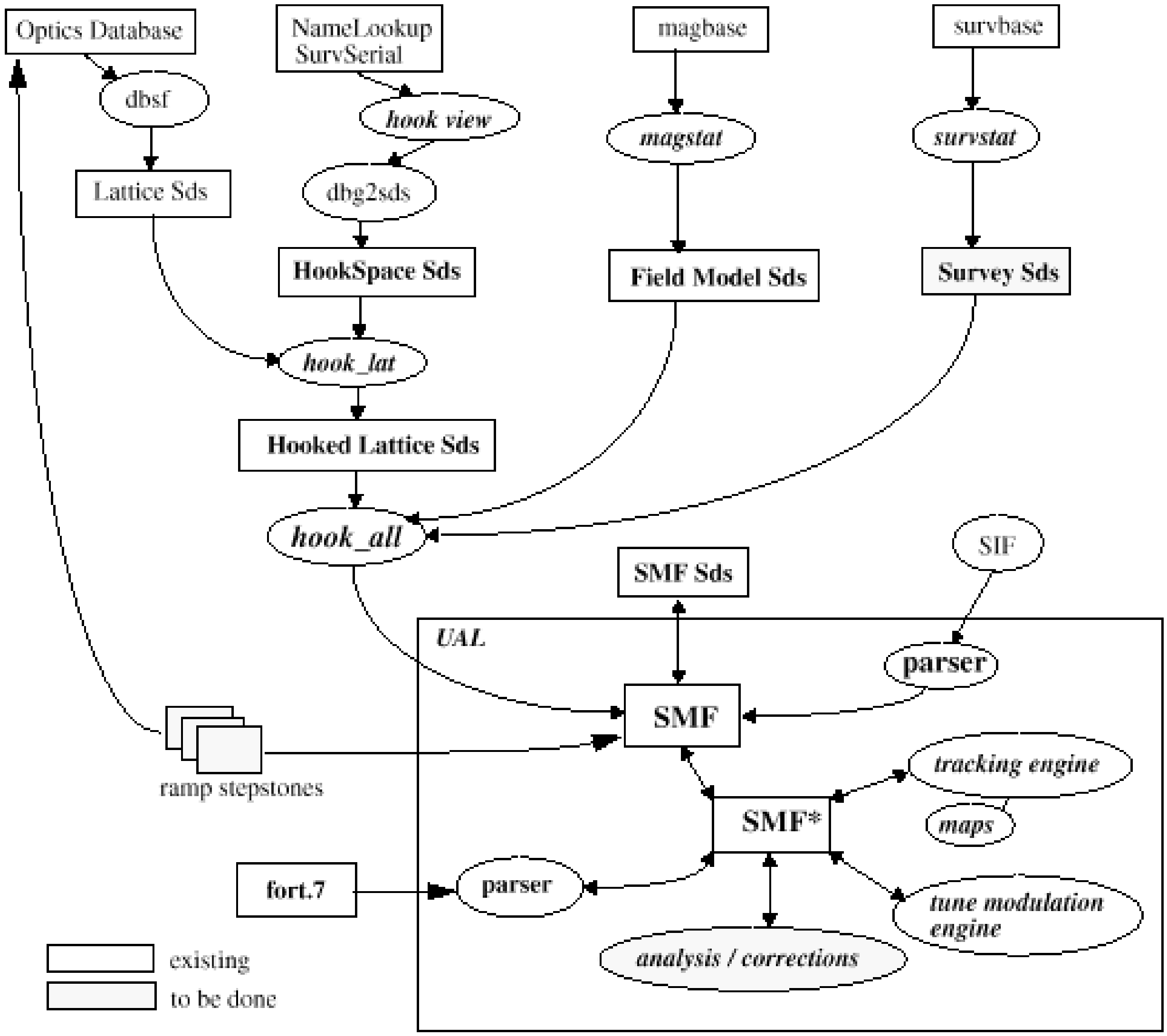

Figure 1: Overview of RHIC SMF

[5] for its data representation. This lattice SDS file acts as an information tree for RHIC installation and configuration as it is used as input to the construction of the *NameLookup* structure.

The first pass in the generation of *NameLookup* is made with a C++ program. It is then loaded into the database as a relational table, and the completion of filling is accomplished by joining the NameLookup table with other tables in the RHIC configuration databases. For example, the correlation of the site name of a magnet with its serial number defined at the factory is stored in the NameLookup table after a join to tables in the magnetic field quality database. The NameLookup table is the primary source of name correlation for installation and operations. (Since NameLookup is needed independently of the SMF for installation and operations, we have not tried to re-design what is clearly a very convoluted data flow in order to make the SMF creation process simpler.)

3.2 HookSpace and HookedLattice

The next stage is the construction of the so-called Hook-Space and HookedLattice structures. HookSpace is created by selecting a subset of the NameLookup data as well as some extra construction details of the quadrupole/corrector assemblies which are only stored in the magnetic field quality database. HookSpace is then melded with the flat lattice SDS structure via a C++ program (*HookLat*) to create a HookedLattice SDS structure. The HookedLattice is a flat SDS data structure with all the data as well as the informational links necessary to construct the four levels of the SMF.

3.3 Magnetic Field Quality

The RHIC Magnet Production Group maintains an extensive field quality database [6] based on warm and cold tests of the super-conducting magnets used in RHIC. This database was created mainly for the purposes of magnet construction and testing. Weekly reviews of the quality of new magnets are conducted based on this data.

Accelerator physicists use a copy of this database (re-generated weekly from the source maintained by the Magnet Group) on their relational database server to analyze field quality for its implications for the stability of beam dynamics. A significant level of computation is required to convert the raw field quality data into a form more useful for this purpose. The result of these computations is saved as a flat SDS C structure called *FieldModel*. Each magnet in FieldModel is keyed to the HookedLattice structure by its magnet serial number. FieldModel contains for each magnet both the values of all deviations for each magnetic multipole tested at various currents as well as the mean and standard deviations of the ensemble of magnet measurements.

3.4 Survey and Alignment

The RHIC Survey and Alignment group has prepared a database structure to record the results of all alignment activities before and after installation of equipment in the RHIC tunnel. The raw data is stored in a set of relational database tables, and programs are used to determine deviations from the ideal locations defined by the lattice design. At present the alignment results are not incorporated in the SMF. In a manner similar to the FieldModel, we will eventually construct an *AlignmentModel* SDS structure appropriately keyed to the lattice so that this data may also be included in the fourth level of the RHIC SMF.

4 SMF GENERATION PROCESS

By joining the HookedLattice structure with the magnetic field quality (and eventually, the alignment) data, we are ready to produce the RHIC SMF. The C++ program *HookAll* reads the information contained in HookedLattice, associates magnetic errors to individual elements from FieldModel, and fills the four level SMF structures.

If a magnet is installed and has been measured cold, we use individual measurements, otherwise we assign the average of measured data relative to that particular type of magnet (DRG, main arc dipole, QRG, main arc quadrupole, QRI, interaction region triplet, and so on for all magnet types). The model can be dynamically updated as soon as new data for magnets are stored in the database. An interesting new feature of the SMF description is that any element (at the GenericElement level) contains Body and End parts. One can then associate body and end harmonics to each thick element without having to add non physical thin multipole elements to the lattice for the sole purpose of carrying errors. This results in a cleaner description where only physical elements are represented.

Once the RHIC SMF is instantiated (see again Figure 1) one can access the UAL (Unified Accelerator Libraries) package [2] and use its tools and physical libraries. A tool has been developed that writes (and reads) an SMF in memory to (from) an SDS file, allowing an external representation of the SMF classes. More recently [2] an ascii external representation of the SMF has been written using the Perl language. The SMF representation can be automatically converted to an SMF***** representation which closely maps the Teapot internal structures, allowing us to use the physical libraries of Teapot++: the teapot tracking engine along with its newer map and tune modulation capabilities. For reasons of backwards compatibility a parser from SIF (Standard Input Format) to SMF has been written as well as a parser from and to the “fort.7” teapot machine file. The latter has been widely used in RHIC for a variety of applications and it is important to retain the capability of accessing it from SMF.

We used the SMF representation of RHIC to perform short term tracking and compared the outcome with results from previous simulations run on Fortran Teapot. The SMF/Teapot++ results are in perfect agreement with the SIF/Fortran Teapot.

5 CONCLUSION

The model of the accelerator provided by the SMF is the most complete and detailed available. It does not assume that magnetic elements are approximated by “thin” kicks, and without loss of generality allows for unusual structural details that may only be needed for special applications such as the insertion of maps. We have used this model in tracking studies to understand the effect of measured multipole fields on the RHIC dynamic aperture and additionally for the study of tune modulation, spin rotators and other non-linear effects. In the future the SMF will become part of the online model of RHIC. Currently, the SMF representation for RHIC is large, easily encompassing over 10 MB of memory, and we expect to see some performance degradation as the size of the SMF increases. Fortunately, it is possible to use the model at either generic or fully instantiated levels, and this makes it possible to adjust some of the simpler operational parameters in a way distinct from those requiring more detailed studies. The advantages of having a single accurate representation of the machine rather than several versions requiring heterogeneous methods to manage them is expected to pay for the added discipline and complication that the model introduces.

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