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A LEGO PARADIGM FOR VIRTUAL ACCELERATOR CONCEPT

Abstract

The paper considers basic features of a Virtual Accelerator concept based on LEGO paradigm. This concept involves three types of components: different mathematical models for accelerator design problems, integrated beam simulation packages (i.e. COSY, MAD, OptiM and others), and a special class of virtual feedback instruments similar to real control systems (EPICS). All of these components should interoperate for more complete analysis of control systems and increased fault tolerance. The Virtual Accelerator is an information and computing environment which provides a framework for analysis based on these components that can be combined in different ways. Corresponding distributed computing services establish interaction between mathematical models and low level control system. The general idea of the software implementation is based on the Service-Oriented Architecture (SOA) that allows using cloud computing technology and enables remote access to the information and computing resources. The Virtual Accelerator allows a designer to combine powerful instruments for modeling beam dynamics in a friendly to use way including both self-developed and well-known packages. In the scope of this concept the following is also proposed: the control system identification, analysis and result verification, visualization as well as virtual feedback for beam line operation. The architecture of the Virtual Accelerator system itself and results of beam dynamics studies are presented.

The physical and mathematical models of a beam line

The Virtual Accelerator package implements a unique hybrid approach to modeling the dynamics of the beam, based on a combination of a large number of proven methods of analysis based on a combination of numerical and symbolic operations.

The VA package allows users:

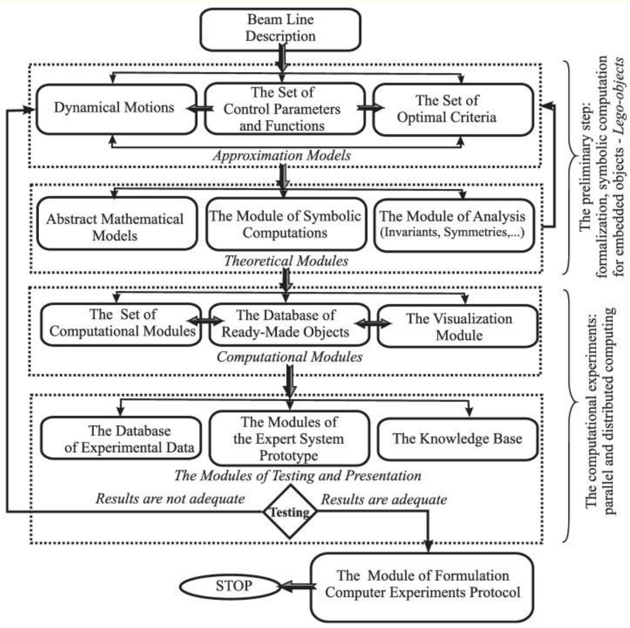
- to combine proven components models with virtual models of new components;
- to develop reliable data on the beam with a virtual simulation and, if possible, the results of environmental tests;
- to improve the accuracy and speed of simulation at the system level, using real data and reliable virtual model;
- to adapt the virtual assembly control system for assessing critical characteristics of the beam;
- to estimate the characteristics of the whole control system before natural testing of a prototype.

The LEGO-technology

The **LEGO**-object has of property of minimality.
The further decomposition is impossible.
The properties of a universality and abstracting are proper in **LEGO**-objects.
The **LEGO**-objects are created for all levels of a computer model. In the offered approach of the **objects-solution** are based.
The main emphasis is made on their **calculation, performance** and **storage**.

The **LEGO**-objects are **compared** to **all methods**, participating during simulation, objects etc.
There are the following main types of **LEGO**-objects:

Describing dynamical systems with control
Describing methods for solution of evolution equations
Describing beam phase portrait and other characteristics
Describing interaction forces presentation (including space charge forces)
…

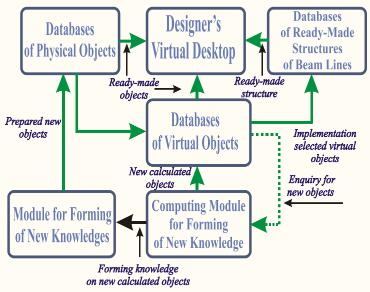


All elementary blocks have their representatives on all phases of modeling process: from physical up to computing models. Including and exclusion either elementary block must be realized quietly, without distortion of the whole model. This approach is realized using *dynamic modeling paradigm* [8].

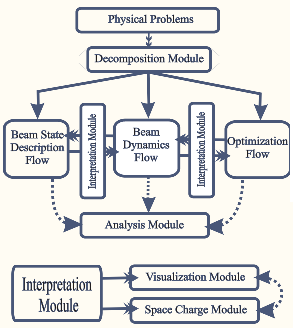
Dynamic modeling paradigm **is a modeling process when models by its self or their sub-models are consider as objects, supplied both expert systems attributes and ``splicing'' of these objects into super-objects.**

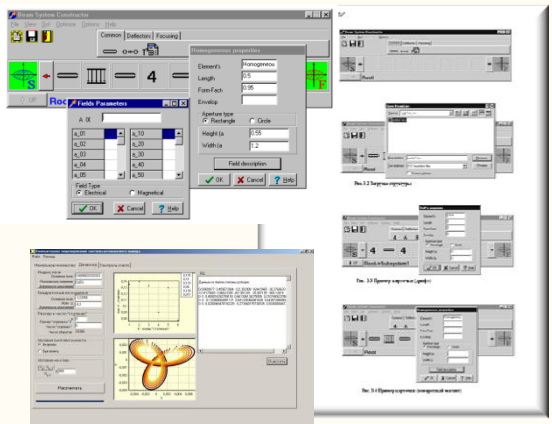
The modeling process (including optimization procedures) has several major phases:

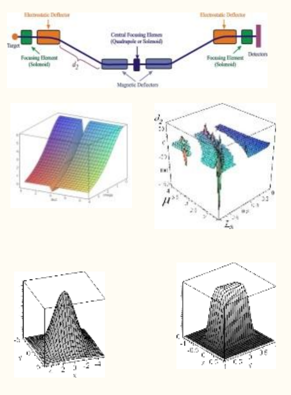
- **the initial phase of problems formalization on physical understanding level – creation of a set physical models for problem under consideration;**
- **construction of approximating models in conformity with experiments data – creation of a hierarchy of approximating models;**
- **the phase of problems formalization on mathematical understanding level – creation of a hierarchy of mathematical models;**
- **creation of computing models (including algorithms and corresponding software) realized mathematical models;**
- **realization of the computing process for modeling and optimization - a set of computing experiments;**
- **the phase of the interpretation of computing results and testing on adequacy to the physical model.**



An Example of Interaction of Different Parts of a Computer Model







Conclusion

The above described approach can be realized using two mathematical and computational frameworks. The first is enough traditional for the most published Virtual Accelerator concept: a combination well known and approved beam line packages and EPICS instruments. The second is based on the first approach (based on numerical modeling first of all) and more extended application of symbolic computational procedures. In our case we use the matrix formalism for Lie algebraic tools [9]. This approach gives the designer more effective and extensible toolbox. The most of modules presented on the figures were realized using this formalism and were applied for different problems of beam physics (see, for example, [1], [10], [11]).

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