STEP-to-ROOT – from CAD to Monte Carlo Simulation

2012 J. Phys.: Conf. Ser. 396 022050

(http://iopscience.iop.org/1742-6596/396/2/022050)

Journal of Physics: Conference Series **396** (2012) 022050 doi:10.1088/1742-6596/396/2/022050

STEP-to-ROOT – from CAD to Monte Carlo Simulation

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Abstract. Modern experiments in hadron and particle physics are searching for more and more rare decays which have to be extracted out of a huge background of particles. To achieve this goal a very high precision of the experiments is required which has to be reached also from the simulation software. Therefore a very detailed description of the hardware of the experiment is needed including also tiny details.

To help the developers of the simulation code to achieve the required level of detail in geometry a semi-automatic tool was developed which is able to convert geometry descriptions coming from CAD programs into ROOT geometries which can be used directly in any ROOT based simulation software.

1. Introduction

In the design phase of an experiment typically two different development branches are ongoing in parallel: The mechanical design of a detector done by engineers and the Monte-Carlo simulation of the detector done by physicists. To ensure that the experiment in its actually realized form matches the expected physics performance, a close interaction between these two branches is of utmost importance. The communication and the data exchange between these two groups are complicated by the different tools used for the different tasks which are in general incompatible with each other. There are on one side computer aided design programs (CAD) for the mechanical design and on the other side GEANT [1] or ROOT [2] based simulation programs for the study of the physics performance.

In order to bypass this difficulty a converter was written which allows a semi-automatic conversion of CAD files based on the STEP data exchange standard to ROOT files for simulation programs.

In the next section the different geometry models are briefly introduced before in the following section the layout of the conversion program is shown. This is then followed by a section showing two examples of the usage of the program.

2. Comparison between CAD data model and ROOT data model

In most modern CAD programs like CATIA® and Autodesk® Inventor® shapes are treated as boundary represented objects (BREPS). This means that an object is made of a set of bounded surfaces (typically basic ones like plane, cylindrical, conical, spherical, toroidal, swept surfaces or b-spline surfaces) where the boundaries are defined by lines, conics, polylines, surface curves or b-spline curves. For example a box is made of six plane surfaces each surface delimited by four straight lines. Each solid is then placed by a translation/rotation matrix in an assembly of many solids and other assemblies forming a complete hierarchy of geometrical objects.

In ROOT and GEANT the constructive solid geometry (short CSG) approach is followed. This means that each solid is created out of a set of simple shapes like cuboids, cylinders, prisms, pyramids, spheres, cones and Boolean operations between them. The newly created solids out of the Boolean operations can then be placed by translation/rotation matrices in assemblies like it is done for the CAD data.

The advantage of the CSG approach compared to BREPS is that the implementation is easier and they are faster to calculate. The drawback on the other hand is that not all objects can be created in a CSG model.

The main task of the converter is to analyse the BREPS shapes to find the matching basic solid in a CSG representation and to extract the parameters of the basic solid.

3. The STEP-to-Root converter

3.1. Design Choices

To be compatible with different CAD programs it was decided to use a widely supported exchange standard of CAD data called STEP (Standard for the exchange of product model data) [3].

In addition it was decided to utilize an open source software package called OpenCascade [4] which is used for reading in the STEP files and convert them into the data objects of OpenCascade. These data objects are then used by the converter to analyse the objects and translate them into ROOT compatible data objects which are then used to generate the geometry output file.

3.2. The layout of the converter

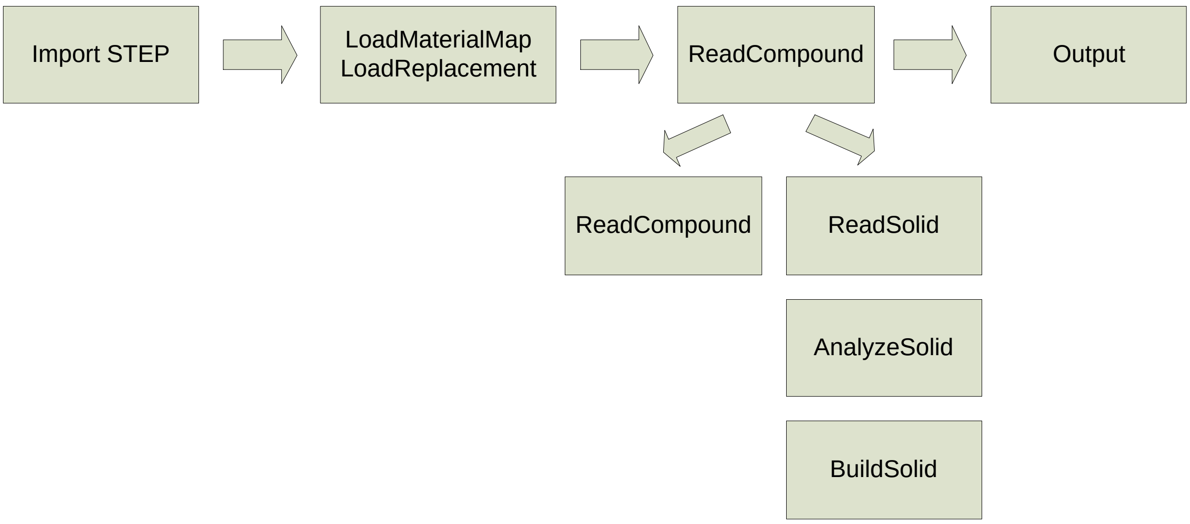

Figure 1. Flow chart of the STEP-to-Root converter.

The flow chart of the STEP-to-Root converter is shown in Figure 1. The first step is the import of the STEP file which is done by OpenCascade.

In the second stage two additional ASCII files are loaded: the material map and the replacement file. The material map is necessary because the STEP file does not include any material information. Therefore, this data has to be given in a separate file. The file consists of two tab separated columns. The first contains a part of the name of a solid and the second column the name of the material which will be assigned to all solids which contain the string given in the first column in their name. A set of predefined materials is provided in the converter. This list can easily be extended by the user to be able to have self-defined materials. For the PANDA experiment, the material parameters of the objects are replaced by the parameters in the Monte Carlo simulation software of PANDA (PandaROOT) [6] to ensure that the parameters used in the simulation are identical for all imported geometries.

The replacement file is needed for the replacement mechanism which is explained in Section 3.3.

ReadCompound is a recursive method which reads in all assemblies and solids of a geometry hierarchy starting with the top volume. If it is an assembly its placement matrix is extracted with the method ReadCompound. If it is a solid, first the solid information is taken from the OpenCascade classes in the ReadSolid step. The solid is then analysed (AnalyzeSolid) in order to determine which type of simple solid it is and its parameters are extracted. At the end the extracted data is stored by the BuildSolid step in an internal data class.

In the Output step the internal data objects are translated into output objects which could be either ASCII strings in an ASCII file or native ROOT objects in a ROOT file. In addition two more files are created. One file which contains the names of the objects that could not be translated and a second file with all the names of objects where no material was assigned.

3.3. Replacement mechanism

In case it is not possible to translate a certain CAD geometry into a basic solid, or the translation is not desired because the geometry is too complex (i.e. direct conversion would cost too much time in the Monte Carlo simulation to propagate particles through the solid): for these cases a replacement mechanism is available in the converter which allows to replace any assembly or solid by a different geometry. Three different ways for the replacement of geometries exist:

- StringPart
  The replacement geometry is given as a string describing a basic solid (e.g. BOX, TUBE, CONE, SPHERE), its parameters and a positioning matrix
- StepPart
  The replacement geometry is given as an additional STEP file which will be automatically loaded by the converter
- RootBooleanPart
  The most powerful replacement mechanism is a Boolean combination of various STEP files. It allows performing Boolean operations on various assemblies and solids given in an unlimited number of STEP files. Supported are the Boolean operations union, intersection and subtraction. In addition the operations can be structured by using brackets.

Which assembly is to be replaced, by which method and with which parameters is given by the so called replacement file which is given before the conversion process as an ASCII file to the converter.

4. Examples

The CAD converter is used to generate the geometry description of two components of the PANDA [5] detector: the Micro Vertex Detector (MVD) and the Solenoid Magnet.

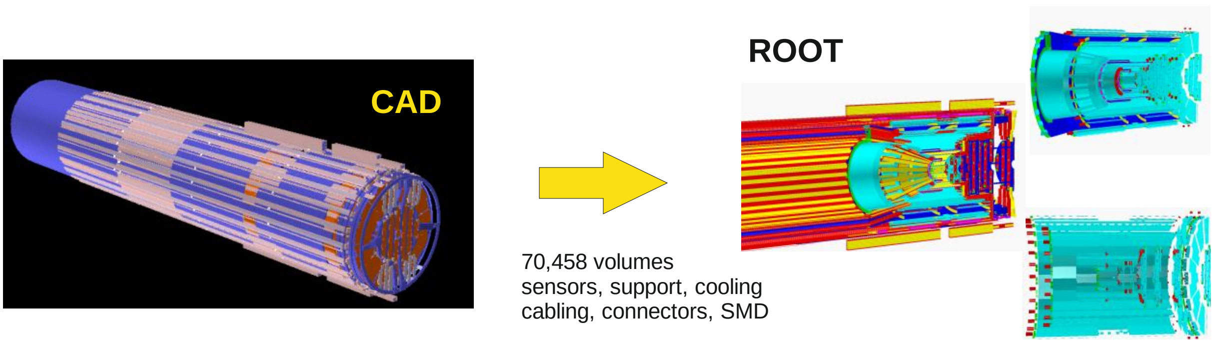

Figure 2. Conversion example: PANDA Micro Vertex Detector [7]

The original CAD drawing and the converted ROOT drawing of the MVD can be seen in Figure 2. More than 70,000 single volumes are converted including sensors, electronics, cabling, cooling, connectors and even tiny capacitors and resistors. This makes the MVD the most accurately described detector component within the PANDA simulation software [7].

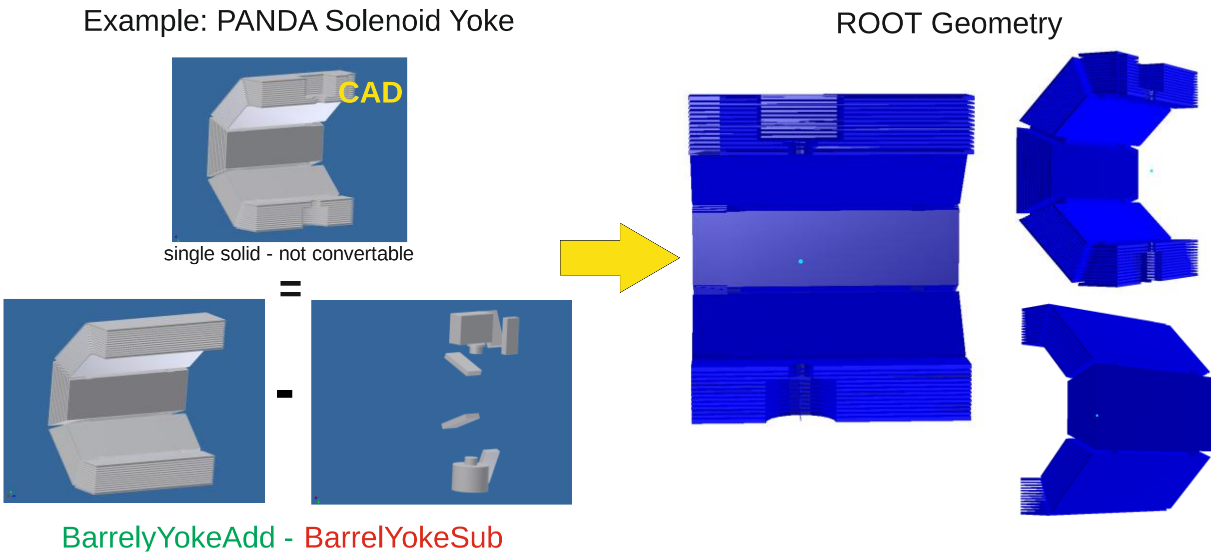

Figure 3. Example for a replacement of the PANDA Solenoid Yoke by a RootBooleanPart. Top left figure shows the original CAD drawing of the single yoke. This single part is divided into two CAD drawings, one with all sub parts which are added together and one where all the parts are in which are subtracted from the first drawing. The resulting ROOT geometry can be seen in the right part of the diagram.

For the conversion of the solenoid magnet the problem was not the huge number of components but the complexity of the single solids. An example can be seen in Figure 3 showing the magnetic flux return yoke. This is one object in the CAD drawing that is impossible to directly translate it into a CSG geometry. Thus the RootBooleanPart replacement mechanism was used for the conversion. Two new drawings were produced: one subdivided the single solid of the yoke into 83 subparts which are all basic geometries which can be translated in the converter. The second drawing contained volumes representing the holes inside the yoke. In the Boolean operation the second STEP file was subtracted from the first STEP file resulting in a ROOT geometry matching the original CAD drawing (see right part of Figure 3).

5. Summary

The STEP-to-Root converter is a program which helps the programmer of a ROOT based simulation software to translate existing CAD drawings into ROOT objects which can be used in the simulation. Due to the difference in the geometry description of CAD programs and ROOT a complete conversion of all possible geometries is impossible. To bypass this restriction a replacement mechanism was introduced which allows to replace every CAD solid by a different geometry which can either be easier to translate or faster to simulate.

This software was successfully used in the PANDA experiment to translate thousands of objects from simple ones like boxes and tubes up to complex objects like the magnetic flux return yoke of the PANDA solenoid.

References

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