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The CADINT Interface in GEANT

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Abstract

We describe the neutral file interface CADINT implemented within the GEANT physics simulation package. The interface allows transfer of detector models from GEANT to Computer Aided Design systems. This paper focuses on the technical details of the interface.

1 Introduction

The engineering work in High Energy Physics for design, analysis and manufacturing of detectors requires Computer Aided Engineering (CAE) tools. To ensure coherent design the same detector descriptions should be used by physicists, engineers and, eventually, manufacturers. Correct exchange of data between CAE tools and the GEANT physics simulation package [1] is crucial.

The CADINT interface allows the export of detector models from GEANT to Computer Aided Design (CAD) systems. CADINT outputs detector models in the SET (Standard d'Echange et de Transfert) [2] neutral file format. A detector model is written as an assembly of solid volumes in a global coordinate system. The geometric representation used is Constructed Solid Geometry (CSG) [3]. A general description of the CADINT interface can be found in [4]. The interface is integrated into GEANT as of version 3.16.

The CADDFAS service [5] at CERN can be used to convert SET files into IGES format (Initial Graphics Exchange Specification, the American standard for exchange of CAD data) [6], which may be read by most CAD systems.

2 SET file format

SET is the French standard for the exchange and archiving of CAD data. It was developed as a neutral file format for exchanging data between different CAD systems at Aerospatiale in 1983. The aim was to develop a more reliable alternative to IGES. It became an official French standard, SET (Afnor Z68-300), in 1985, and it was revised and extended in 1989. The version (89-06) used in CADINT supports wireframe, surface and solid entities. Entities for drafting and connectivity applications, as well as scientific data and FEM (Finite Element Method) modelling are also included. It is considered to be important to have an unambiguously defined format that is compact in size, and is flexible enough to handle future demands from the CAD/CAM industry.

The structure of SET is based upon a three-level hierarchy of data assemblies, data blocks, and data sub-blocks. Information that is common to several blocks or assemblies is stored in a so-called dictionary. The description of these components is the following:

- **Assembly:** this is a collection of data defining a certain piece of information, such as a mechanical part. A SET file can contain one or more data assemblies.
- **Block:** in the terminology of the SET files, blocks are identified by an @, followed by the number of the block identifying its type. This number is followed by the block's reference number in the file (i.e. in a file with n blocks, the block sequence numbers will be from 0 to n). After this, the sub-blocks and dictionary entries used in the block follow. A SET data block is an elementary entity which consists of definition or control data that are used in different applications. Such entities could be geometric objects such as points or lines, or other entities like matrices, drawings and views or SET file identifiers.
- **Sub-block:** this consists of an identifier, and a list of data that contributes to the description of the entity defined by the data block. The different parameters inside a sub-block, such as coordinates, are represented by their values. A sub-block has the identifier "#", followed by its type number, possible references to the dictionary, and parameters applicable in the sub-block.
- **Dictionary:** this is a set of predefined parameters in the specifications of the standard. They are accessible as dictionary entries which are assigned an identifier (a colon ":" and the dictionary number), and a precise meaning given by authorised and/or default values.

References among entities in a SET file are made by using pointers, either directly from the blocks, or via sub-blocks or dictionary entries. Pointers to other blocks are identified by an "!", followed by the sequence numbers of the blocks. SET has no unique mapping of sub-block types and dictionary entries into blocks. Several combinations are allowed for each different block. Definitions of possible combinations and guidelines for implementation are given in the SET standard [2].

3 Implementation

In the CADINT interface, a user can indicate a subtree of a detector by giving the name of the volume at the top of the subtree, and all the contents of this subtree will be written into a SET file. A user can also tailor the contents by setting the daughter volumes to be visible or invisible using the GEANT visibility attribute, and only the visible volumes will be written. In order to avoid repetition, a representative number of division instances can be chosen. The colours of volumes defined by the GEANT colour attribute are also transmitted into SET files.

The CADINT interface writes the geometry of a GEANT detector model in the SET file format in two basic phases: volume information and position information.

The interface outputs volumes into the SET format as CSG solids. Division instances are treated as normal volumes, i.e. every instance is a distinct solid in a SET file. An index is attached to the name of each of the division instances in order to distinguish them. The indexing is reset for each division. An index is attached to the name of multiple instances of normal volumes as well. All solids are positioned in the global coordinate system. The GEANT tree structure is not transmitted into the SET format, i.e. daughter volumes occupy the same space with their mother volume. The material information is written into a separate file, called the material file, together with the GEANT tree structure.

The interface decodes the data stored in the JVOLUM data structure, and computes the necessary parameters (unknown volume parameters, dimensions of division instances, coordinates, etc.). These computations are based on the GEANT drawing routines. The interface decodes a detector model starting from the global mother volume, i.e the root node of the tree. After that it decodes the first daughter volume on the left side of the tree. It continues decoding daughter volumes until it is at a leaf node of the tree. After that the interface returns one level and decodes the next daughter of the current volume if any exists. In a case of a divided volume, the division instances are treated in the same way as the daughter volumes. The creation of the SET file and the material file is performed during the decoding.

3.1 Volume information

The tree decoding routine transfers the volume information during decoding to the relevant shape routine which writes the volumes into the SET file. Every different shape has its own routine. For example, the simplest shape, BOX, is written in the SET format as follows:

```
@50,N1,:5,2#60,X,Y,Z
@302,N2#317,-DX,-DY,-DZ
@100,N3,:5,2,:9,'Name'#101,!N1,!N2
```

where

- `@50` is the block number which defines a primitive solid;
- `N1,N2,N3` are the sequence numbers of each block;
- `:5,2` is the dictionary entry number which gives a total subordination to one block;
- `#60` is the sub-block number which defines the geometric parameters of a solid rectangular parallelepiped;
- `X,Y,Z` are the dimensions of the rectangular parallelepiped;
- `@302` is the block number for geometric transformation;
- `#317` is the sub-block number for translation;
- `DX,DY,DZ` are the coefficients of the translation;
- `@100` is the block number which defines a constructed solid;
- `:9` is the dictionary entry number for a name associated with the block;
- `Name` is the name of the volume;
- `#101` is the sub-block number for transformation operation.

The rectangular parallelepiped is first defined with the given parameters and after that the translation of coordinates. This is necessary since GEANT and SET use different origins. Finally, the transformation operation is defined for a constructed solid (in this case the translation of the coordinates of a primitive solid). The GEANT shapes are converted to SET as shown in table 1.

3.2 Position information

The tree decoding routine transforms the coordinates and the rotation matrix of a volume to the global coordinate system, and then transfers the data to the routine which writes it into the SET format as follows:

```
@302,N1#301,M1,M2,M3,M4,M5,M6,M7,M8,M9,XC,YC,ZC
@100,N2,:9,'Name'#101,!N1(of the shape),!N1
```

SHAPE	DEFINITION IN SET
BOX	rectangular parallelepiped
TRD1	ruled solid between 2 faces
TRD2	ruled solid between 2 faces
TRAP	ruled solid between 2 faces
TUBE	solid of revolution of a face
TUBS	solid of revolution of a face
CONE	solid of revolution of a face
CONS	solid of revolution of a face
SPHE	sphere
PARA	ruled solid between 2 faces
PGON	first segment ruled solid, other segments copied and rotated, finally boolean union for all the segments
PCON	solid of revolution of a face
ELTU	solid of linear extrusion of a face
HYPE	not implemented
GTRA	ruled solid between 2 faces
CTUB	solid of revolution and boolean subtraction by 2 half-spaces

Table 1: Definitions of the GEANT shapes in SET.

where

- `@302` is the block number for geometric transformation;
- `N1,N2` are the sequence numbers of each block;
- `#301` is the sub-block number which defines the coefficients of the rotation-translation matrix;
- `M1...M9` are the coefficients of the rotation matrix;
- `XC,YC,ZC` are the components of the translation vector;
- `@100` is the block number which defines a constructed solid;
- `:9` is the dictionary entry number for a name associated with the block;
- `Name` is the name of the volume;
- `#101` is the sub-block number for transformation operation;
- `!N1` is the reference to sequence number of the mother volume.

The geometric transformation is first defined with the given parameters and then the transformation operation is defined for a constructed solid. The principle of writing divisions into the SET format is equivalent to the case of normal volumes.

3.3 Material and tree information

The material file is written into a separate file in parallel with the SET file. It contains information on the tracking medium, material and density for each defined volume. The GEANT tree is written into this same file. The volume name is followed by the number of daughters and daughter names. In a case of divided volume, the negative number of divisions is given after the name of the divided volume, and followed by the offset, step and the name of the division instance. An output of a material file of a GEANT example program:

```
  GEANT-SET MATERIAL LISTING FILE
  --------------------------------
  Materials in the geometry described in
  the .SET file:  gexam4.set

Volume name  Tracking media   Material          Density

CALO          1 AIR            1 AIR             0.12000001E-02
CAL1          1 AIR            1 AIR             0.12000001E-02
MOD1          1 AIR            1 AIR             0.12000001E-02
CAL2          1 AIR            1 AIR             0.12000001E-02
MOD2          1 AIR            1 AIR             0.12000001E-02
CAL3          1 AIR            1 AIR             0.12000001E-02
MOD3          1 AIR            1 AIR             0.12000001E-02
EPO1          4 CARBON         4 CARBON          0.22650001E+01
CHA1          6 BRASS          6 BRASS           0.85600004E+01
TUB1          6 BRASS          6 BRASS           0.85600004E+01
GAS1          5 GAS            5 ARG/ISOBU       0.21360000E-02

  GEANT TREE
  ----------
   The GEANT tree starting from the given volume

CALO    6  CAL1  CAL2  CAL3  EPO1  CHA1  EPO1
CAL1  -64  -0.48000000E+02  0.15000000E+01  MOD1
CAL2  -35  -0.43750000E+02  0.25000000E+01  MOD2
CAL3  -13  -0.24050001E+02  0.37000003E+01  MOD3
CHA1  -40  -0.25000000E+02  0.12500000E+01  TUB1
MOD1    6  SHIL  URPL  SHIL  EPO1  CHA1  EPO1
MOD2    4  SHIL  URPL  SHIL  CHA2
MOD3    2  COPL  CHA2
TUB1    1  GAS1
CHA2  -72  -0.23500000E+02  0.65277779E+00  TUB2
TUB2    1  GAS2

        ------ end of file -------
```

4. Conclusions

The technical details of the CADINT interface implemented for the GEANT physics simulation program have been presented. It allows transfer of detector models from GEANT to CAD systems. Detector models are described in SET files which may be processed by CAD systems.

Problems which are caused by data structure limitations in CAD systems can be avoided. If the system is not capable of receiving the whole detector model in a single SET file, the model can be transferred in smaller parts. These parts can then be joined together. Division instances can be suppressed using the relevant attribute in the interface. They can be reproduced in CAD systems, if needed. Volumes made of gas or fluid can be suppressed using the GEANT visibility attribute. Volumes can be differentiated by colours using the GEANT colour attribute. Colours can be used in order to help to distinguish different volumes (e.g. division instances, etc.). The tree information provided in the material file can be useful for engineers to understand the structure of the GEANT detector model.

The GEANT version 3.21 Boolean operations are not implemented in the interface. They can be reproduced in CAD systems after transfer. However, this can be implemented in the CADINT interface as well.

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[5] For more information about the CADDFAS service, see the CADD WWW home page at "http://cadd.cern.ch/cadd_front.html".

[6] US department of Commerce, Initial Graphics Exchange Specification (IGES), 1988.