Geant 4

GEOMETRY

User Requirements Document

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INTRODUCTION

Purpose of the document

This document collects the specific requirements concerning the Geant4 Geometry modeler expressed by users. Generic requirements are collected in the Geant4 User Requirement Document.

Scope of the software

The geometry module in Geant4 provides software for modeling geometrical structures representing detector apparatus where to perform physics simulation. It also provides instruments for generically handling navigation and positioning of particles in the geometry model utilizing efficient and high precision algorithms, in presence or not of electromagnetic fields.

Product perspective

The geometry modeler is one of the Geant4 Toolkit kernel modules.

General capabilities

The user shall be able to define the geometry of a detector.
The user shall be able to define an electromagnetic field map.
The user shall be able to apply geometrical biasing.

General constraints

Geant4 Geometry modeler must be compatible for usage with the Geant4 Toolkit.
The user will be able to customize services in a suitable way for his/her specific applications.

User characteristics

User communities interested in the Geant4 geometry modeler are physicists and simulation experts in different domains: high-energy and nuclear physics experiments, astrophysics and astroparticle experiments, and medical physics groups.

Operational environment

The software will be for use in a Unix and Windows environments with an ISO compliant C++ compiler, according to the software specifications included in the main User Requirements Documents of Geant4.

Assumptions and dependencies

This document relies on the assumption that Geant4 modeler software will be supported and the project adequately funded.

SPECIFIC REQUIREMENTS

Capability requirements

Detector construction

UR 1.1 The user shall be able to define the geometrical volumes by assigning the parameters of geometrical entities (*Ref. UR 4-1, and #6*).

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 1.2 The user shall be able to define physical detector elements by specifying their geometrical representation and also their chemical, tracking and hit related information (*Ref. UR 4-2, and #7*).

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44
Clarity: Clear.
Verifiability: Verified.

UR 1.3 The user shall be able to detect clashing / physically overlapping volumes (*Ref. UR 4-3, and #8*).

Need: Useful.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 1.4 The user shall be able to define sub-detector regions where to apply specific production cuts (*Ref. UR 19-16, and #62*).

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: CMS, BaBar experiments.
Clarity: Clear.
Verifiability: Verified.

UR 1.5 The user shall be able to retrieve all relevant attributes associated to a geometrical entity (material, sensitivity, visualization attributes, transformations, etc.) and eventually modify them.

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 1.6 The user shall be able to import and export geometry descriptions from/to a persistent format. The persistent data model must cope with the transient representation of the geometrical entities.

Need: Useful.
Priority: Partially implemented.
Stability: Stable.
Source: LCG.
Clarity: Clear.
Verifiability: To be verified.

Electromagnetic field

UR 2.1 The user shall be able to define the electromagnetic field map (*Ref. UR 3-1, and #5*).

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 2.2 The user shall not have to calculate the step size for integrating the equation of motion (*Ref. UR 7-2, and #18*).

NOTE: to set the step size, the following factors have to be taken into account:

1. Interactions integrated in space-time (like energy loss and multiple scattering);
2. The occurrence of processes which introduce a discontinuity in the spatial trajectory (decay, electromagnetic or hadronic interaction);
3. The occurrence of processes affecting the time of the tracks (processes at rest, fluorescence);
4. Any combination of the above cases;
5. The step being limited by the path length to the volume boundary.

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 2.3 The user shall be able to optimize the tracking by setting the accuracy for the trajectory in electromagnetic field (*Ref. UR 7-4, and #20*).

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 2.4 The user shall be able to choose among different algorithms for step integration according to the kind of field involved in the simulation (uniform, non-uniform, specific pattern-dependent, etc.)

Need: Established.
Priority: Implemented.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: To be verified.

UR 2.5 The user shall be able to define different accuracy for the field according to the particle tracked.

Need: Established.
Priority: Implemented.
Stability: Stable.
Source: CMS.
Clarity: Clear.
Verifiability: To be verified.

UR 2.6 The user shall be able to define uniform or non-uniform magnetic fields.

Need: Established.
Priority: Implemented.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 2.7 The user shall be able to define a 'non-magnetic' field (electric field).

Need: Established.
Priority: Implemented.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: To be verified.

Solids & volumes

UR 3.1 The user shall be able to construct in a 'intuitive' way the major geometrical CSG shapes like: box, cylinder and cylinder shell, sphere and sphere shell, cone and cone shell, generic trapezoid, poly-cone and polyhedron, torus and torus shell.

Need: Essential
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 3.2 The user shall be able to define in a 'intuitive' way the major geometrical shapes as bounded-represented solids (BREPs).

Need: Useful
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: To be verified.

UR 3.3 The user shall be able to define bounded-represented solids (BREPs) generated from 2^{nd} or higher order surfaces. He must be able also to generate generic advanced shapes generated by patching linear surfaces.

Need: Useful
Priority: To be defined.
Stability: Stable.
Source: RD44.

Clarity: Unclear.
Verifiability: To be verified.

UR 3.4 The user shall be able to compose generic solids through Boolean operations on CSG shapes: union, subtraction and intersection.

Need: Established
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 3.5 The user shall be able to associate logical attributes to geometrical entities, like: material definition, detector element sensitivity, detector region and field map, visualization attributes.

Need: Established
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 3.6 The user shall be able to slice a detector element in many equal portions (replicas) along Cartesian or rotational axes and in a generic way (i.e. independent from the associated CSG shape type).

Need: Established
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 3.7 The user shall be able to replicate the same detector element in different positions in the geometry tree through a parameterisation applied to either positioning and dimensions or associated material.

Need: Established
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR 3.8 The user shall be able to divide a detector element in different portions (divisions) along Cartesian or rotational axes, and define generic offsets between the represented portions. Divisions should apply to relevant CSG shapes.

Need: Useful
Priority: Implemented.
Stability: Stable.
Source: CMS.
Clarity: Clear.
Verifiability: To be verified.

UR 3.9 The user shall be able to reflect along a specified axis a hierarchy of volumes defining a detector geometry tree (*Ref. UR #76*).

Need: Established
Priority: Completed.
Stability: Stable.
Source: Alice, CMS.

Clarity: Clear.
Verifiability: To be verified.

UR 3.10 The user shall be able to retrieve the geometrical entities generated from the reflection of a geometrical tree. Given a volume it must be possible to retrieve its reflected counterpart, if any (*Ref. UR #80*).

Need: Established
Priority: Completed.
Stability: Stable.
Source: CMS.
Clarity: Clear.
Verifiability: Verified.

UR 3.11 The user shall be able to define group of volumes in an assembled structure, according to a well-specified positioning pattern.

Need: Established
Priority: Completed.
Stability: Stable.
Source: KEK.
Clarity: Clear.
Verifiability: Verified.

UR 3.12 The user shall be able to choose the portion of a detector or geometry structure where to perform optimization techniques for efficient navigation.

Need: Useful
Priority: Completed.
Stability: Stable.
Source: CMS.
Clarity: Clear.
Verifiability: Verified.

UR 3.13 The user shall be able to compute the approximate volume mass and/or density of a generic geometrical entity.

Need: Useful.
Priority: To be assigned.
Stability: Stable.
Source: IN2P3, NASA.
Clarity: Clear.
Verifiability: To be verified

Navigation & transportation

UR 4.1 Advanced users shall be able to customize the way navigation and transportation is performed in a geometry setup.

Need: Useful.
Priority: Implemented.
Stability: Stable.
Source: BaBar, Alice.
Clarity: Clear.
Verifiability: To be verified.

Biasing

UR 5.1 The user shall be able to apply event biasing and sampling techniques, by specifying particle and geometry dependent importance (*Ref. UR 19-15, and #61*)

Need: Essential.
Priority: Implemented.
Stability: Subject to change.
Source: ESA joint project.
Clarity: Clear.
Verifiability: Verified.

Constraint requirements

Detector construction

UR A.1 Geant4 shall be compliant with the STEP standard at the geometrical modeller level and also for the exchange of geometrical data (*Ref. UR 14-1, and #43*).

Need: Useful.
Priority: Implemented.
Stability: Stable, but can evolve.
Source: RD44.
Clarity: Clear.
Verifiability: Continuous verification.

UR A.2 The system must be able to detect and notify the user about improper or illegal geometry constructions, according to the established specifications (*Ref. UR #75*).

Need: Useful.
Priority: Implemented.
Stability: Stable, but can evolve.
Source: RD44.
Clarity: Clear.
Verifiability: Continuous verification.

UR A.3 It must be possible to restrict the area of analysis for detecting volume overlaps in a complex geometry structure.

Need: Useful.
Priority: Implemented.
Stability: Stable, but can evolve.
Source: CMS, ATLAS.
Clarity: Clear.
Verifiability: Continuous verification.

Electromagnetic field

UR B.1 The tracking of a particle shall be achieved by integrating the equation of motion in the magnetic and electric field over successive steps whilst simultaneously taking into account the effects of the presence of matter (*Ref. UR 16-1, and #45*).

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR B.2 The tracking of a particle's spin shall be achieved by integrating the Bargmann-Michel-Telegdi equation over successive steps (*Ref. UR 16-2, and #78*).

Need: Established.
Priority: Completed.
Stability: Stable.
Source: TRIUMF.
Clarity: Clear.
Verifiability: Verified.

UR B.3 It must be possible to associate different fields (field type and/or field intensity) to different regions of the same detector setup.

Need: Established.
Priority: Completed.
Stability: Stable.
Source: BaBar, ATLAS.
Clarity: Clear.
Verifiability: Verified.

UR B.4 It must be possible to set regions of the same detector setup with 'zero' field assigned, without inducing penalties in tracking performance.

Need: Established.
Priority: Completed.
Stability: Stable.
Source: ATLAS.
Clarity: Clear.
Verifiability: Verified.

UR B.5 The transportation of particles in presence of field must be performed efficiently, by providing reasonable precision with a default tuning of the relevant parameters, and by allowing automatic detection of possible looping particles.

Need: Established.
Priority: Completed.
Stability: Stable.
Source: CMS, ATLAS.
Clarity: Clear.
Verifiability: To be verified.

Solids & volumes

UR C.1 It must be possible to specify a displacement for one of the solids that are composed through Boolean operations.

Need: Established.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR C.2 It must be possible to define angular sections of solids: cylinder, cone, sphere, torus, poly-cone and polyhedron.

Need: Established.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR C.3 Replication of volumes must be performed efficiently in terms of memory consumption and parameters setting.

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR C.4 Optimization techniques must be applied independently from the type of volume or positioning in the geometry structure.

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

Navigation & transportation

UR D.1 Navigation of particles in the detector geometry must happen in a transparent way to the user, independently from the geometry setup (structured or not structured), positioning types (single placements or replications), solid types or optimizations. Navigation must be performed efficiently.

Need: Essential
Priority: Completed.
Stability: Stable.
Source: RD44
Clarity: Clear.
Verifiability: Verified.

UR D.2 It must be possible at any point in time of the simulation to locate a point in the detector setup and determine the relevant geometrical information related to its position.

Need: Essential
Priority: Completed.
Stability: Stable.
Source: RD44
Clarity: Clear.
Verifiability: Verified.

UR D.3 Transportation must treat transparently to the user the propagation of particles in the detector with or without presence of electromagnetic field.

Need: Essential.
Priority: Implemented.
Stability: Stable.

Source: RD44.
Clarity: Clear.
Verifiability: Verified.

General

UR E.1 The memory requirements for the Geant4 object model for the geometry shall be comparable with the ones of GEANT3 (*Ref. UR 13-1, and #41*)

Need: Desirable.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

UR E.2 The searching time scanning the geometrical database during the tracking shall be comparable with GEANT3 (*Ref. UR 13-2, and #42*)

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified and faster.

UR E.3 The user shall be able to use simple GEANT3 geometry definitions (*Ref. UR 19-8, and #55*)

Need: Useful.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified (via ASCII files, no need to interfaces to Fortran).

UR E.4 Memory management for geometrical entities and volumes allocated should be automatically performed by the system, allowing also for dynamic modifications of the geometry setup at run time.

Need: Essential.
Priority: Completed.
Stability: Stable.
Source: RD44.
Clarity: Clear.
Verifiability: Verified.

DOCUMENT STATUS

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0	0	12 January 1995	Created
0	1	14 July 1996	Finalized general requirements status
1	0	10 February 2004	Added and updated granular requirements Formatted as Microsoft Word document