GEOMETRY LOADING TIME STRATEGY

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An ongoing problem, to various degrees is an anomalous load time for the CAD derived geometry. This geometry uses a commercial software packages, FastRAD[1], to convert the CAD drawings of the MICE beam channel into a machine readable format (GDML [2]). In the current implementation, these GDML files are again translated into the MICE model handling format (MICEModules, see Ref. [3]) before being read into the GEANT4[4] simulation. When the system was first implemented, using GEANT4.9.2, loading times greater than 120 minutes were observed for the Step IV geometry. This time has decreased to 20 minutes with an upgrade to GEANT4.9.6. The problem is known to be in the placement of the objects used to describe the beam line components (Tessellated solids) and not explicitly related to the handling of these objects in MICEModules. This is a problem primarily for cases were the a fast simulation time is valuable, either for debugging purposes or for online simulation during data collection. This is not a great problem for batch simulation production as the parameters used in the production may be manipulated to make appropriate use of computing resources.

This method of defining the geometry based on the CAD drawings was made so that the geometry of the MICE channel may be defined based on engineering specifications, validated in a controlled manner, and stored in a centralized place that is under version control (The configuration data base). This avoids the problems of having multiple people changing the geometry definition leaving little or no corporate memory of what those changes were, why they were made, or what came before. There are a number of possible solutions for the loading time problem that may be explored that still incorporate the good parts of the CAD implementation. These are either software solutions or changes in approach that may be taken to reduce the simulation loading time.

1. Trimmed Simulation Geometry

This solution has already been explored to some extent. By reducing the geometry to consist of only detector elements and magnetic fields, with no CAD derived Tessellated solids, the loading time is reduced to less than 2 minutes. The information from the engineering specifications are still used to define the detector positions. This is considered suitable for debugging as all of the active elements in the geometry are included. However, it is not suitable for online use as the important scattering surfaces of the beam line are absent.

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This solution may be extended by determining the identity of the scattering surfaces and simulating only those surfaces. Now all elements of the beam line are simulated whether they are exposed to the beam or not in some detail. By reducing the detail, or more specifically the number of tessellated solids in the simulation, the loading time will be greatly reduced.

The steps needed to implement this approach is to identify the scattering objects, and assess the level of complexity required for the purposes of simulation. For example, the quadrupoles consist of copper coils contained in iron housings. If particles do not scatter off of the copper and continue to the detectors, there is no need to simulate the copper elements, and it may be sufficient to just simulate the iron elements. Similarly, if any two iron elements are in contact, it is not necessary to simulate them as separate objects. This activity will require a physics study to define the important scattering surfaces before removing and simplifying objects in the CAD description. This could be approached by systematically turning volumes in the beam line into sensitive detectors to evaluate how often particles interact with the volumes, and how momenta are changed by the interaction.

2. Load from GDML

There are modules in GEANT4 that allows GDML to be loaded explicitly—this is why GDML is the output from FastRAD which is itself based on GEANT4. Loading the GDML description of the StepIV geometry into a GEANT4 example that uses GDML to load the geometry takes on the order of 5 to 10 minutes. This decrease in loading time may be due to an optimization of the internal algorithms used by GEANT4 to read and load these objects.

An attempt has been made to integrate the GDML parser into MAUS. What has been learned so far is that the standard algorithm used to load GDML files into GEANT4 is not comparable with the MAUS geometry construction algorithm making bridging the two approaches a non-trivial exercise. Furthermore the it is not know whether the sensitive detector modules are compatible with the GDML implementation as some of these modules themselves contain elements of the geometry which will need to be extracted and passed into their definitions. Additionally the GDML format does not contain field information so this information will need to be added after the geometry via the existing MICEModule framework.

3. GEANT4 Upgrade

The central problem is the treatment and manipulation of tessellated solid objects. This is an active area of development by the GEANT4 collaboration. A bug fix between g4.9.2 and g4.9.6 allowed for the previous observed speedup, and the optimization of tessellated solids is a work package of a group under AiDA. A new version of GEANT4 has been released that has not yet been tried in MAUS: GEANT4.10.0. Given recent developments, and depending on how one parses the literature, there may have been further updates to the handling of tessellated solids. Given that g4.10.0 represents improvements in other realms it may be valuable to make this migration independent of the geometry loading time issue.

4. Regression from CAD geometry

Given the problems with the tessellated solids it may be necessary to avoid their use completely. This does not necessarily mean not using the engineering drawings of the MICE beam line or migration from GDML format, as there is further value to using the GDML for parsing information. Rather, if the beam line elements are modelled using primitive solids, and placed along the beam line, in much the same way that the detectors are now. The standard GEANT4 solids (spheres, boxes, cylinders, etc.) can be defined in GDML and are much more efficiently modelled and placed by GEANT4. The detectors and absorbers are already defined in this way. The benefits of the current approach can be preserved, while avoiding the prohibitive load times. This activity will require a user to visually inspect all of the beam line volumes and replace them with combinations of primitive solids. This activity need only be done once for the beam line objects and future CAD releases can be edited to incorporate these replacements. Furthermore not all of the tessellated solids need be replaced. There is a large number of volumes, such as the tracker solenoid cryostats and the diffuser barrel, that should be modelled using combinations of primitives rather than computationally intensive tessellated solids.

5. Summary

The cause of the long loading times observed in the CAD based MICE geometries are the result of placing a large number of solid objects described using tessellated solids. This is the default object type provided by CAD to GEANT4 conversion programs including FastRAD. The assumption is that the loading time is proportional to some combination of the number of tessellated solids used by the geometry and the number of facets used to describe those solids. The current loading times are on the order of 20 minutes for the Step IV geometry. An acceptable loading time must be defined to determine the scope of the activities described here.

A number of possible courses are described here with various levels of risk versus the potential benefit. Upgrading to the latest release of GEANT4 may provide some benefit in this regard, but the effect in loading times is possibly a secondary concern to other benefits including increased functionality, multithreading, and improved physics lists. This should be the first of the recommendations considered. Trimming the CAD geometry will require a physics study before engaging Jason Tarrant to simplify the CAD description in a motivated way. If this cannot reduce the number of files loaded by a factor necessary to produce the acceptable load time, a regression of the CAD geometry using primitive solids will be well motivated. Loading the geometry from GDML will require a reorganization of the MAUS detector simulation with an as yet unknown scope. It is not clear that this activity will bear direct benefits to MICE beyond a simplification of handling the geometry description — no conversion of the geometry files will be required after download — in addition to an as yet unknown, fixed decrease in the loading time.

The upgrade to GEANT4.10 takes first priority with an expected completion prior to the end of June. Evaluating the practicality of using the GDML directly will take more time with completion at the end of October. If these solutions do not yield satisfying results then the alternatives of trimming the simulation and otherwise reinterpreting the simulation should be explored. The initial study time could take on the order of 1 month with the time between iterations dictating the time to the conclusion of the study.

References

[1] FastRAD website `http://www.fastrad.net`
[2] GDML Users Manual `http://lcgapp.cern.ch/project/simu/framework/GDML/doc/GDMLmanual.pdf`
[3] MAUS Users Manual `http://micewww.pp.rl.ac.uk/maus/MAUS_latest_version/maus_user_guide/index.html`
[4] S. Agostinelli *et.al.*, Nuclear Instruments and Methods in Physics A 506 (2003) 250-303