IRIS-HEP Summer 2024 Fellows Program Project Proposal

Development of flexible interface for rapid geometry modelling and exchange between CAD tools and simulation platforms dedicated for HEP experiments

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Simulation of complex HEP detection setups is critical to the understanding of the expected low-level response of respective sub-detectors, and reconstruction performance for crucial quantities such as impact parameters or lifetime of unstable composite particles or radiation damage. In each case, a detailed geometry of the detector is crucial for configuring the simulation chain. Building complicated geometry using custom HEP tools is typically very time-consuming and complex from the coding point of view. On the other hand, many enterprise tools offer high-quality interfaces for prototyping, templating and integrating complicated geometries. In this project, we propose to study the possibility of creating a custom interface between professional tools for complicated geometrical building and HEP platforms such as Geant or Fluka. If successful, such a tool would bring a much more reliable way of preparing and testing complicated detector models for the HEP community.

This project stands out for its focus on improving the utilisation of CAD-type geometries within Geant4 simulations. It is unique in its emphasis on developing a multifunctional toolkit for managing multiple CAD geometry elements and a rapid conversion mechanism for STL files to Geant4-compatible formats. These innovations, along with the design of a user-friendly interface for streamlined geometry configuration, are the main objectives of this project. We need to prepare a comprehensive development environment and establish a foundational understanding of the relevant libraries and tools, such as Geant4, STL, CAD, and GDML formats. Early efforts are directed towards creating a basic application framework in Geant4 that integrates initial STL/CAD geometry loading capabilities. This task is not trivial, and often, it is a significant entry threshold for people starting their activities in this field. One of our objectives is to streamline this process and define the software stack configuration easily and transparently.

As the project progresses, advanced features for dynamic geometry management are implemented. These allow for the handling of multiple independent geometry elements that can be modified without recompilation through external configuration files, such as TOML. This setup facilitates the addition, removal, and modification of geometries in a flexible manner.

A significant portion of the project is dedicated to the user interface development, which involves prototyping and implementing a tool (either command-line based or graphical user interface) that allows users to configure and manage geometries easily. This interface supports the precise positioning and configuration of multiple geometry elements as dictated by their original CAD specifications.

Parallel to interface development, the project focuses on creating a high-efficiency wrapper for the conversion of STL files into Geant4-compatible formats. This wrapper integrates seamlessly with the developed tools, ensuring that the conversion process is both quick and accurate,

catering to a variety of geometry complexities and configurations. In the final stages, comprehensive testing of the application is conducted to ensure that all components, including geometry loading, simulation processing, and user interface functionality, operate cohesively and effectively. The project concludes with the finalisation of detailed documentation to aid both users and future developers and a report summarising the progress and outcomes.

In summary, we aim to significantly enhance the capability of Geant4 simulations to integrate and manage complex CAD geometries more effectively and intuitively. By developing a suite of tools that simplify the processes of geometry manipulation and conversion, this initiative promises to advance the field of simulation by making sophisticated geometrical simulations more accessible and manageable for researchers and engineers alike.

Project Timeline Overview

Weeks 1-12:

- Throughout the project duration, focus on understanding the libraries and tools that support CAD-type geometry in simulations. Learn to effectively utilize STL geometry within Geant4. This ongoing familiarization process will provide the necessary foundation for tool development and integration. The final goals are to develop tools for handling multiple CAD geometry elements simultaneously, create a wrapper for rapid conversion of STL files to Geant4-compatible formats, and design a user interface for easy geometry configuration and management. .

Week-by-Week Breakdown

Weeks 1-2: Initial Setup and Planning

- Set up the development environment.
- Create a project repository and establish version control practices.
- Review Geant4, STL, CAD, and GDML formats and tools.
- Develop a barebones Geant4 application framework.
- Begin initial documentation covering project setup and basic usage.

Weeks 3-5: STL/CAD Integration

- Research and document existing tools and libraries for loading STL/CAD geometry into Geant4.
- Develop and test a basic module for loading STL/CAD geometries into Geant4.
- Incorporate the STL/CAD loading feature into the barebones Geant4 application.

Weeks 6-8: Geometry Management and Simulation

- Implement functionality to handle multiple independent geometry elements from CAD without recompiling the application.
- Develop mechanisms to add, remove, and modify geometry elements through external configuration files (e.g., TOML).
- Integrate sensitive detector definitions into the geometry elements.
- Test and validate the integration with simple geometry setups.

Weeks 9-10: Conversion and Optimization

- Design and prototype a user interface for configuring geometries,(e.g. command-line based TOML configuration or a simple GUI overlay).
- Implement the chosen user interface for basic geometry management.
- Refine the user interface for ease of use and enhanced functionality.
- Ensure the interface allows for configuring multiple geometry elements and setting their positions as defined in the CAD models.
- **Develop and integrate a wrapper for rapid conversion of STL files to Geant4-compatible formats, incorporating all features developed during the project**.
- Optimize the conversion process for efficiency and accuracy.
- Conduct thorough testing and validation with various geometry configurations and complexity levels.

Weeks 11-12: Final Integration and Testing

- Conduct comprehensive testing of the entire application, including geometry loading, simulation, and user interface.
- Debug and resolve any issues or inconsistencies identified during testing.
- Finalize documentation, including user guides and developer notes.
- Plan for future enhancements or maintenance tasks post-deployment.
- Preparing a report on the progress made.