PhD offer
Compact mesh generation for geological models

March 27, 2025

Keywords : Mesh generation, polyhedral partition, Geological 3D models, implicit surfaces.

Context

One of the fundamental challenges of geology is to understand the soil, the subsoil and its history, which makes it of great importance to society. Mapping the different types of underground rocks is the key to optimal access to water and natural resources. Knowledge of soils and their chemical composition is necessary to ensure the viability of certain plant species, and thus protect biodiversity. Finally, the study of the physics and history of landscapes improves our understanding of risks, which is key to anticipate and prevent landslides, floods, coastal erosion, etc.

One of the key challenges in the field for interactive visualization and physical simulation is to digitalize the soil and subsoil in 3D with explicit mesh-based representations. Acquired on site, geological knowledge is traditionally interpolated with implicit functions that predict the shape in the 3D space of various geological objects such as subsoil layers or faults [WC18]. Mesh generation techniques [DZCJ22, AJR+20] are then used to create a mesh data structure that conforms to the zero value of implicit functions. These mesh generation techniques however suffer from several issues. They typically produce dense meshes, conform poorly to implicit surface intersections or discontinuities, and scale poorly to large scenes.

Objectives

The main objective of this PhD is to design and implement solutions to the mesh generation problems mentioned above. In particular, the PhD candidate will investigate efficient and scalable algorithms that can produce lightweight 3D meshes whose cells conform to the implicit functions and their intersections. One of the main challenges will be to minimize the number of implicit function evaluations, as they often are computationally expensive. Several research axes will be studied.

Adaptive grid generation. The state-of-the art approach in geological modeling software is traditionally based on adaptations of *marching elements* algorithms (marching tetrahedra, cubes, etc.). In these methods, implicit functions are first evaluated on the vertices of a mesh, and there will be as many evaluations as vertices. We will improve the approach developed by [DZCJ22, JDZ+24] trying to minimize the number of evaluation vertices.

Polyhedral partitioning by plane collision. The candidate will investigate a mesh-based representation that takes the form of a polyhedral partition that can describe both surface elements with polygonal facets and volume elements with polyhedral cells [BL20, OL24]. These elements will have to be enriched by input-induced semantic knowledge and globally optimized to avoid spatial inconsistencies. One possible way to explore this will be to build the partition incrementally by inserting planar sections that interpolate the input implicit functions. Similarly to [SL24], a tree structure as a binary space partitioning tree will potentially be used to track the construction and modifications hierarchically.

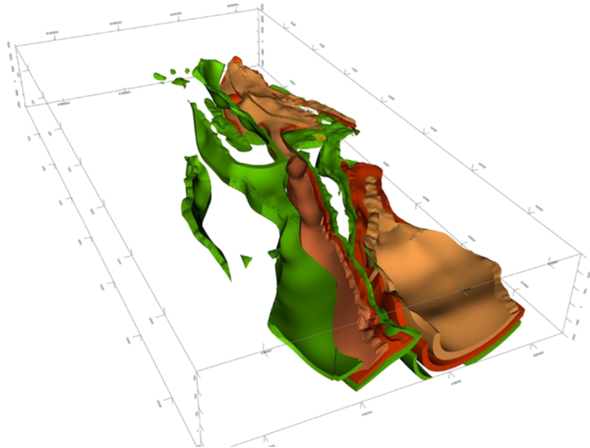

Figure 1: 3D model of geological formations in the Pyrenees (Martel et al., 2025). The accurate and lightweight discretization of such geological layers is important both for visualization and applications like flow simulations.

Piecewise-planar interpolation of geological data. The input of the previous approach is a dense set of points, which generally requires several evaluations of the underlying implicit functions. Instead of discretizing implicit functions by dense sets of points that are later interpolated by planes with planar shape detection algorithms [YL22], the candidate will investigate direct interpolation of input geological data by planes successively generated from the input data points.

Practical Information

This PhD proposal is part of a larger "Defi" project between BRGM and INRIA. The candidate will be integrated into a multidisciplinary team that includes members of both institutes.

- **Candidate profile:** good knowledge in computational geometry and/or geometry processing and/or applied mathematics, be able to program in C/C++, be fluent in English, and be creative and rigorous.
- **Location of the PhD thesis:** Inria Sophia Antipolis, France
- **Contacts for application:** Florent Lafarge (Florent.Lafarge@inria.fr) and Simon Lopez (s.lopez@brgm.fr)
- **Application deadline:** 16th of June, 2025
- **Expected start:** Autumn 2025

References

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