Title: Leveraging Topological Analysis of an Algebraic Structure for Parallel, Distributed, and Out-of-Core Mesh Modeling and Manipulation in the Context of Medical Imaging Visualization.

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Context and thesis description:

Advances in medical imaging, such as magnetic resonance imaging (MRI), have led to a massive increase in the volume and resolution of data to be analyzed. For instance, our partner, the CHU of Poitiers, with its 7T MRI system, has greatly confirmed this trend by capturing intricate details of living organisms and producing images with various modalities. To develop efficient tools for exploring and visualizing such data, it is crucial to design accurate and suitable mesh models. These meshes, often large and complex, present significant challenges in terms of storage, manipulation, and the execution of complex operations.

The use of a geometric structure to represent meshes derived from medical imaging often relies on managing adjacencies and incidences between different topological cells. To address this, XLIM has developed a set of tools dedicated to the structure of Generalized Combinatorial Maps (G-maps), named Jerboa, which exploits graph transformations to describe complex topological operations within a mathematical framework. This novel operation representation formalism has enabled the parallelization of specific processes. Notably, its use in topological analysis algorithms has provided a new perspective on object topology analysis (particularly Reeb graphs), optimizing high-quality processing for medical imaging by robustly and concisely describing complex shapes.

Exploring these mathematical tools opens new perspectives for designing more efficient models suited to parallel and distributed systems, as well as out-of-core architectures (where data cannot be fully loaded into memory), aimed at volumetric visualization of medical imaging meshes.

Thesis Objectives:
This thesis aims to improve mesh manipulation for the visualization and processing of medical imaging data by leveraging the Jerboa formalism. Specifically, it focuses on:

- Applying new parallel topological invariants for topological analysis;
- Developing a convexification operation (to produce convex volumetric meshes) as a parallel and distributed process;
- Managing memory efficiently to handle complex operations on meshes that cannot fully fit in memory.