A Parallel Delaunay and Advancing Front Mesh Generation Approach

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1 Introduction

The increase of computing power for multiphysics simulations results in a growing number of requirements/constraints for mesh generation as well as more complex and, often at the same time, bigger structures to be treated. This calls for the deployment of high performance mesh generation tools. At the same time the quality of the mesh is not only critically important for the quality of the calculated results, but failure to properly control the meshing process can jeopardize or even completely prevent simulation. The availability of robust high performance tools is therefore of utmost importance.

The current trend of increasing the amount of cores in a single processor instead of increasing the brute performance of a single core requires parallelization techniques to make use of the computational power. This circumstance adds to the already formidable complexity of mesh generation, as geometrical and topological consistency has to be ensured, which requires particular attention in a parallel setting and necessitates the use of advanced programming techniques and paradigms to be implemented efficiently.

We present an approach to parallel meshing based on a combination of Delaunay and advancing front algorithms, which yields suitable results for both finite elements and finite volume discretization schemes. Our approach first ensures that the input hull meets the constrained Delaunay property [6]. It then proceeds with the generation of the mesh by using an advancing front algorithm specially adapted to consistently provide elements fulfilling the Delaunay property and avoiding colliding fronts.

The main advantage of our approach is the ability to generate meshes using local feature size criteria, while being compatible to the upcoming multi-core processor designs by making use of state of the art programming techniques and paradigms. Current compiler technologies such as the parallel STL which is part of GCC 4.3 [2] are accounted for and combined with already established partitioning tools such as METIS [3].

The introduced approach is based on a surface treatment algorithm in order to satisfy the constrained Delaunay property for the hull first. A subsequent advancing front algorithm is specially adapted to comply with the consistent Delaunay property to circumvent colliding fronts.

Important advantages of our approach are the enabling of full utilization of upcoming multi-core processors and the mesh size optimality based on a local feature size criterion.

All mesh generation and adaptation algorithms were newly developed with modern programming paradigms. Current compiler technologies, e.g., the parallel STL of the new GCC 4.3, are thereby automatically incorporated.

2 The Meshing Approach

A major drawback of most Delaunay algorithms is the requirement to enclose the initial input in a convex hull, from which the desired mesh has to be extracted. We avoid this complicating step by first applying a surface treatment which ensures that the surface remains unchanged during the course of the following meshing steps, which results in a decisive simplification for the parallelization. This stage also offers itself well to interface already established utility libraries for parallelization such as METIS [3], which can be used to further subdivide the surface into parallelly tractable parts.

The subsequent advancing front algorithm has two modes of operation. The first in which the Delaunay property is ensured, which prohibits the insertion of additional points [6]. The second mode of operation is free to insert new points on demand to optimize the overall mesh quality [5], however, it does not guarantee the Delaunay property.

Due to its incremental nature the advancing front algorithm does not distinguish between mesh generation and mesh adaptation. Mesh adaptation is therefore simple and is easily done in parallel by removing unfavorable elements and subsequently starting mesh generation for the created space.

A given mesh can therefore be easily adapted using our parallel meshing approach. Due to the constrained boundary representation and the advancing front, all subdomains can be adapted in parallel.

3 Programming Paradigms

The combination of geometrical and topological issues places algorithms related to advancing front mesh generation among the most complex fields of programming. Problems with the robustness of geometrical algorithms for instance can yield topological inconsistencies, while topological problems, such as crossing elements, can adversely effect successful termination of the meshing algorithm. The matter of consistency is even more pronounced in a parallel environment, where consistency between the concurrent parts has to be accounted for explicitly.

To deal with these issues, we have separated the geometrical and topological areas into different programming parts. Geometrical issues are treated by using generic programming and the outsourcing of this treatment into numerical libraries, e.g., interval arithmetic or exact numerical kernels like CGAL [1] or Mauch [4]. Topological issues are stabilized by the Delaunay property. If the geometrical predicates are correct, the element consistency is given by a simple advancing front algorithm.

References

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