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Fast and Parallel Unstructured Mesh Generation for Large-Scale Aerodynamics Simulations

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Most aerodynamics simulation codes have been parallelised in the academic and industry communities. However, as the major performance bottlenecks of complex aerodynamics simulations, mesh generation is usually executed sequentially. Although parallel mesh generation has attracted the attentions of researchers for two decades, the robust codes that can fully parallelise the mesh generation process are still worthy of detailed investigation to attain a comparable maturity with the parallel simulation codes.

First of all, we will discuss the sequential algorithms developed by us that can accomplish the preprocessing steps for unstructured mesh based aerodynamics simulations, i.e., (1) automatic element sizing definition and smoothing, (2) robust advancing front surface meshing; (3) fast and robust Delaunay tetrahedralisation; (4) aggressive improvement of the tetrahedral mesh. Furthermore, we will discuss the parallelisation techniques of these sequential algorithms. The domain decomposition (DD) approaches involved are highlighted. The DD regarding the parallelisation of a simulation code is essentially a graph partitioning problem, and can now be solved with vastly available open-source tools such as Metis or ParMetis. However, the DD for parallel mesh generation is more complicated, which involves some specific geometrical and load-balancing issues that have not been fully resolved so far. Meanwhile, great efforts are required to improve the performance of both the domain decomposers and the parallel meshers and improvers in terms of efficiency, reliability and element quality.

Finally, several examples are selected to show that the developed parallel preprocessing pipeline is robust and applicable to geometries of a complication level experienced in industry.

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