Abstract

Numerical simulation techniques for complex physical problems are widely adopted by the industry as a part of the industrial design cycle. These simulations are often performed on computational grids, where the physical domain is subdivided into simpler shapes. It is claimed that, the computational grid plays an important role on the accuracy and the computational efficiency of the numerical solution. Among few types, hexahedral grids offer the best solution in these terms.

Generation of the hexahedral grids is a complex task and the scientific research on hexahedral grids is concentrated on the development of more robust grid generation techniques. However, these methods are often lack mechanisms to control the features of the grids being generated. Automatic control of the hexahedral mesh generation process that will allow producing the highest computational grids with a low cell count will be much appreciated by the industry.

The present thesis is an attempt to introduce such automatic control mechanisms for hexahedral grid generation process. The studies are conducted with a close collaboration with Numeca International, a company that offers industrial solutions for Computational Fluid Dynamics (CFD) simulations, including flow solvers and mesh generators. The thesis study is conducted on an existing overlay-grid based all-automatic hexahedral grid generator. As the basis of the grid control mechanism, spring-analogy based point relocation algorithm is chosen. In this method, the grid is considered as a network of springs under tension, where mesh edges are considered as springs connected at the mesh vertices. Equilibrium positions of the nodes under the spring forces are calculated. The anisotropy of the mesh can be controlled by modifying stiffness of springs in the system.

Overlay grid based methods are often criticised by producing grids with excessive number of cells. This is mainly due to the orientation sensitivity of the method and the excessive refinement iterations to capture the finer details of the geometry. To solve this inefficiency, the mesh generation algorithm is controlled by the spring-analogy based method using anisotropic metrics. The selected metrics contain the local size and direction information, to improve the geometry-awareness of the overlay grid method. The first metric introduced for this purpose is called the Natural metric, which relies on growing an imaginary elastic ball from every point on the medial axis of the geometry. The shape of the ball is interpolated to an ellipsoid in order to calculate anisotropic sizes and directions. The second metric extraction method is based on distance maps computed
on a background grid. It is seen that, using the proposed control algorithm and metrics and the metric fields the number of cells produced by the grid generator can be taken under control. Numerical simulations of external and internal flows performed on the controlled grids suggest that, the final mesh is of high quality and numerical simulations on them give accurate results.

The techniques developed for this thesis is also applied for simulation-time grid control. Moving boundary problems is chosen to demonstrate the potential of the control algorithm in grid post-processing. For this purpose segment-spring approach, where the equilibrium length of springs in the system is considered as the length of the mesh-edges at the initial position, is implemented as grid control mechanism. Using this technique, the optimised shaped of the mesh cells can be preserved. The optimised shapes of the cells near the boundary are kept more carefully in order to achieve better numerical performance. The algorithm is validated on an oscillating airfoil problem.