

OPTIMIZATION OF FINITE VOLUME MESHES USING SPHERICITY

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A method for optimizing CFD meshes, using a geometric quantity called Sphericity, is introduced. Sphericity is an element-wise property that provides a measure of the shapes deviation from a perfect sphere. When used as an objective in a gradient based framework, it results in a fast, scale invariant, optimization algorithm applicable to arbitrary finite volume element topologies. The gradient is calculated analytically using manual differentiation, leading to exact sphericity derivatives w.r.t. the mesh vertex positions. The methodology is heuristic in nature in that it does not consider known numerical quality metrics explicitly. Our study has however shown it to be exceptionally robust and effective in improving mesh quality, as it is shown empirically that the maximization of sphericity inside the computational domain results a global improvement to all other quality metrics, provided that grid topology does not introduce fundamentally concave cells.

The main focus is the development of a robust optimization algorithm that can effectively handle complications arising from constraints imposed by surface interactions. Specifically, efficient heuristic and gradient based techniques, for handling difficult mesh topologies with acutely curved surfaces, feature edges and high aspect ratio layer cells are introduced. In combination with the base method, these measures ensure exceptional quality meshes even on industrial scale applications. In the context of CFD analysis, a mesh displacement algorithm is indispensable in cases with moving boundaries, like shape optimization, aero-elasticity etc. Therefore as a final step, the method is integrated into a general purpose mesh motion framework, allowing the maintenance of high cell quality even during extreme deformation events. Examples and industrial applications in the context of adjoint based shape optimization are presented, illustrating the methods general effectiveness.