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ACCURATE AND ROBUST MULTI-MOMENT FINITE VOLUME SOLVER ON UNSTRUCTURED GRIDS FOR INCOMPRESSIBLE FLOWS

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A robust and accurate finite volume method (FVM) is proposed for incompressible viscous fluid dynamics on unstructured grids including mesh elements of arbitrary shapes, such as triangular or quadrilateral in 2D, and tetrahedron, hexagon, pyramid or prism in 3D.

Different from conventional FVM where the volume integrated average (VIA) value is the only computational variable, the present formulation treats both VIA and the point value (PV) as the computational variables which are interpreted as different moments of the physical fields and updated separately at each time step. The VIA is computed from a finite volume scheme of flux form, and is thus numerically conservative. The PV is updated from the differential form of the governing equation that does not have to be conservative but can be solved in a very efficient way.

Cell-wise interpolation functions are properly designed in terms of both VIA and PV moments. Including PVs at cell vertices as the additional variable enables us to make higher-order reconstructions over compact mesh stencil to improve the accuracy. More importantly, adding the PVs as a new degree of freedom makes the resulting numerical model more robust for unstructured grids even with bad quality in nonorthogonality and skewness.

We verified the numerical formulations in both two and three dimensions on unstructured grids with various types of mesh elements. As justified by the numerical results of benchmark tests, without large increase in algorithmic complexity and computational cost, significant improvements are achieved in accuracy and robustness in comparison with the conventional FVM formulations on unstructured grids. The present method provides a practical solver for incompressible viscous flows which well balances the numerical accuracy and computational complexity.