

論文の内容の要旨

論文題目 Improving Accuracy of Building-Cube Method Using Upwind Interpolation at Hanging Node Interfaces in Compressible Euler Equation Simulations (圧縮性オイラー方程式シミュレーションのハンギングノードインターフェースでの風上補間を使ったビルディングキューブ法の精度向上について)

氏 名 スレトラナート スリカンス

Cartesian grids are gaining importance because of the fewer efforts to be invested in different aspects of simulation like grid generation, higher order scheme implementation, and post-processing. Simulations that use a block structured Cartesian grid approach and where the entire domain consists of different sized cubes/squares with the same number of cells in each cube/square are the Building-Cube Method (BCM) simulations. The presence of adjacent different-sized cubes/squares creates a hanging node interface between them and the cubes/squares in such a domain mutually exchange information with the help of their ghost cells. This research work is being carried out to propose a new interpolation method for obtaining ghost cell values to reduce the bad effect of hanging nodes in the simulation and to confirm its performance by conducting simulations of

- ・ sine wave propagation using two-dimensional wave equation with one-dimensional hanging node interface,
- ・ vortex convection using two-dimensional isentropic vortex equations with one-dimensional and two-dimensional hanging node interfaces,
- ・ and shock wave propagation in a two-dimensional shock tube with a two-dimensional hanging node interface.

Roe scheme with second-order MUSCL extrapolation and Roe scheme with fifth-order WENO extrapolation are used in this research. In all the simulations, the entire computational domain is divided into blocks/regions having different grid spacing. This is done to analyze the flow field when the fluid flows from a finer to a coarser region. The two ways of interpolation used are described below.

The standard way of interpolating values at ghost cells is referred to as standard interpolation in this research. The standard interpolation used for ghost cells of finer blocks at the hanging node interface is a direct transfer of value from the coarse cell to the fine ghost cells. The standard interpolation of coarser block cells is a simple averaging of all values in the fine cells that the coarser ghost cell encloses.

The new upwind way of interpolation proposed here uses the characteristic equations at the hanging node interface. Eigenvalues and eigenvectors are used to determine the flow characteristics and then for transforming the primitive values to characteristic variable values before transferring them to ghost cells either directly or by using higher-order interpolations. Then the characteristic values are transformed back to primitive values for use in simulation calculations.

In sine wave propagation simulation with a simple sine wave traveling from fine to coarse region in the domain, a reflected wave is observed to the left of the one-dimensional hanging node interface while using standard interpolation. This reflected wave is diminished by using a new upwind S2L interpolation, thereby maintaining the magnitude of the original propagating sine wave. From the L2-norm error values and plots, it is confirmed that upwind S2L interpolation performs better than standard interpolation.

For isentropic vortex convection, separate cases of a computational domain having a one-dimensional hanging node interface and a computational domain having two-dimensional hanging node interfaces are both simulated. It is observed that using upwind interpolation generates less error in the domain while using standard interpolation in both these cases. This is also confirmed

by the error in pressure contour plots, L2-norm error in pressure values, and time-averaged L2-norm error in pressure values in the domain.

In a two-dimensional shock tube simulation, with the propagation of a shock wave in the computational flow domain having a two-dimensional hanging node interface, it is observed that using upwind interpolation near the hanging node interface gives more accurate solutions in the domain. The L2-norm error in pressure values, its time history, and time-averaged L2-norm error values in the domain also confirm that upwind interpolation performs better than standard interpolation.

From these simulations conducted in this research, it can be inferred that the accuracy of solutions in simulations using upwind interpolation near hanging node interfaces has improved than while using standard interpolation.