Efficient spatial second-order precision compressible fluid calculation method with resolution equivalent to fifth-order precision

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Abstract

In this study, we move from the MUSCL framework and use the MUSCL-THINC method, which gives the physical quantity distribution within a numerical cell as a hyperbolic function, allowing to sharply capture shock wave discontinuities.

Reasons and benefits of using JAXA Supercomputer System

The effectiveness of the method will be investigated by applying it to various flow configurations such as multiphase flow, electromagnetic fluid, and transonic buffet. These simulations require significant computational power, and therefore the use of JAXA supercomputer is necessary.

Achievements of the Year

The THINC method was originally proposed for multiphase flow interfaces, but preliminary calculations have shown that it is also effective for suppressing the diffusion of weak shock waves such as Mach 1.01. Although this method is an efficient spatial second-order precision method, it achieves a numerical solution with a resolution equivalent to the spatial fifth-order precision, and reduces three to five times the computational cost.

In this year, the unstructured grid extension of MUSCL-THINC is pursued. At the same time, as test cases for comparison purpose, practical aerodynamic simulations such as transonic buffet flow computatoins have been conducted without THINC.

Publications

- Oral Presentations

1) Kitamura, K., Tsukamoto, Y., Wang, Z.-N., Moller, F.M., and Tucker, P.G.: Effects of LES/RANS Hybrid Interface Locationin Shock-Wave/Boundary-LayerInteractions, AIAA-2025-2573, 2025 AIAA SciTech Forum, January 10, 2025, Orlando, FL.

2) Kakimoto, H., Kumai, H., Hara, Y., Oonawa, Y., Kitamura, K., and Nonaka, S.: A Rear-Slanted Protuberance for Side Force Reduction on Slender Launch Vehicle, 16th International Space Conference of Pacific-basin Societies (ISCOPS), Tokachi Plaza, Obihiro, Japan, November 19-22, 2024.

3) Mamashita, T., Fukushima, G., and Kitamura, K.: Application of Hybrid MUSCL-THINC Approach to Magnetohydrodynamic Simulations for Sharply Capturing Discontinuities, [8-A-02], ICCFD12, Kobe International Conference Center, Kobe, JAPAN, July 14-19, 2024.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	48 - 512
Elapsed Time per Case	24 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.11

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	2,678,663.36	0.12
TOKI-ST	18,565.78	0.02
TOKI-GP	0.00	0.00
TOKI-XM	0.50	0.00
TOKI-LM	0.00	0.00
TOKI-TST	26.39	0.00
TOKI-TGP	0.00	0.00
TOKI-TLM	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2 (%)
/home	728.45	0.49
/data and /data2	153,554.84	0.74
/ssd	7,131.59	0.38

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	49.80	0.16

*1: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

*2: Fraction of Usage：Percentage of usage relative to each resource used in one year.

- **ISV Software Licenses Used**

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage*2 (%)
ISV Software Licenses (Total)	325.47	0.22

*2: Fraction of Usage：Percentage of usage relative to each resource used in one year.