Machine-learning based prediction of fluid dynamics

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Abstract

Turbulence models play important roles in the aerospace science and technology, such as flows around aircrafts and of planetary atmospheres. Recently, they are developing rapidly empowered by machine learning methods (Duraisamy, Iaccarino, and Xiao, 2019), and will be a crucial building block of the aerospace science and technology in the near future. The present study is aiming for the integration of physics and data-driven methods for turbulence modeling.

Reasons and benefits of using JAXA Supercomputer System

Machine-learning-based predictions and models of turbulence will be necessary for the future aerospace science and technology. The reason to use JAXA Supercompter System is that we can develop these methods based on training data of turbulent flows with high-resolution, numerical calculations of which require a massively parallel supercomputer.

Achievements of the Year

Machine-learning-based prediction of turbulence relies on much training data; however, such data is hardly available in engineering applications at the high Reynolds numbers. To overcome this difficulty, we proposed, in a paper (Inubushi and Goto), a "transfer learning" algorithm for Reservoir Computing which is a machine learning method suitable for predictions of nonlinear dynamics. Based on the reservoir computer sufficiently trained at the low Reynolds number, we retrained it with a small amount of data at the high Reynolds number and showed that the retrained reservoir computer is effective for an inference task. Moreover, we studied the orbital instability of turbulence, which is one of the important properties for predictions, and characterized it with the Lyapunov analysis.

Publications

- Peer-reviewed papers

Masanobu Inubushi and Susumu Goto, Transfer learning for nonlinear dynamics and its application to fluid turbulence, Physical Review E 102, 043301 (2020).

Usage of JSS

- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	64
Elapsed Time per Case	24 Hour(s)

- **Resources Used(JSS2)**

Fraction of Usage in Total Resources*1(%): 0.04

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2(%)
SORA-MA	155,705.06	0.03
SORA-PP	1,305.74	0.01
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2(%)
/home	533.10	0.49
/data	14,934.55	0.29
/ltmp	8,789.07	0.75

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2](%)
J-SPACE	0.00	0.00

[*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.

- **Resources Used(JSS3)**

Fraction of Usage in Total Resources[*1](%): 0.01

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	2,331.77	0.00
TOKI-RURI	0.00	0.00
TOKI-TRURI	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage[*2](%)
/home	46.73	0.03
/data	5,073.55	0.09
/ssd	238.42	0.12

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2](%)
J-SPACE	0.00	0.00

[*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.