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.

Ref. URL: http://fm.me.es.osaka-u.ac.jp/inubushi/index-j.html

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 JSS2 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

In this year, we have developed a novel machine-learning (ML) method, which enables efficient predictions of chaotic dynamics with a surprisingly small amount of data. By conducting the direct numerical simulations of the Navier-Stokes equations, we have demonstrated that the energy dissipation rate of turbulence can be inferred by the proposed method, which utilizes the knowledge of turbulence from a small amount of training data. We expect that the proposed method provides a basis for the future ML-based turbulence modeling.

Publications

- Peer-reviewed papers

Masanobu Inubushi and Susumu Goto, Transferring Reservoir Computing: Formulation and Application to Fluid Physics, Lecture Notes in Computer Science 11731, 193, Springer (2019).

- Invited Presentations

(1) Keita Kohashi, Masanobu Inubushi, and Susumu Goto, Reservoir computing harnessing spatiotemporal nonlinear dynamics, Nonlinear Theory and Its Applications (NOLTA2020).

- Poster Presentations

(1) Masanobu Inubushi and Susumu Goto, Transferring Reservoir Computing: Formulation and Application to Fluid Physics, The 28th International Conference on Artificial Neural Networks.

(2) Masanobu Inubushi and Susumu Goto, Transferring reservoir computing: formulation and application to fluid physics, Deep Learning and Physics 2019.

Usage of JSS2

- **Computational Information**

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

- **Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.00

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage[*2](%)
SORA-MA	7,954.70	0.00
SORA-PP	526.60	0.00
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	56.27	0.05
/data	5,168.92	0.09
/ltmp	6,835.94	0.58

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.