JHPCN Exploratory Theme ID: EX23305

Advancing the Frontier of Data-Driven Computational Fluid Dynamics

（データ駆動数値流体力学の創成）

PI: Hisaichi SHIBATA, Ph. D., @ The University of Tokyo Hospital

1. Background

Dimensionless Navier-Stokes Eq. — governs → Flows (e.g., Air around an Airplane)

Dimensionless Navier-Stokes Eq. — contains → Reynolds Number

Practical Flows (e.g., Air around an Airplane) — are often → High Reynolds Number Flows

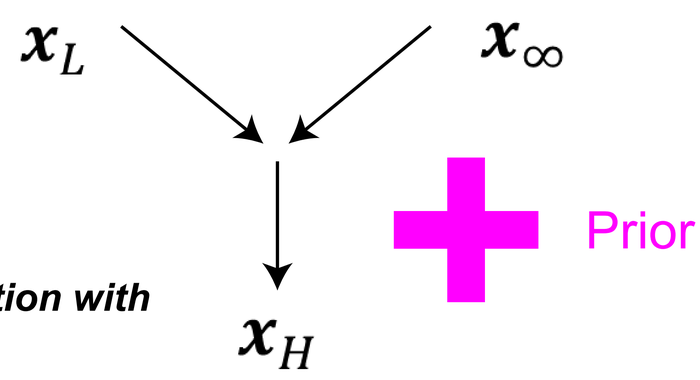
However,

High Reynolds Number Flows — demand → High Computational Cost

2. Objective

Low Reynolds Number Flows

Inviscid Flows



Interpolation with a prior to obtain

High Reynolds Number Flows

with

Low Computational Cost

3. Methods

To model the prior and enable the sampling $x_H \sim p(x_H | x_\infty, x_L)$, I adopt a conditional diffusion model (deep generative model).

<Diffusion Model>

Noise Addition

Denoising (with a deep neural network)

I trained a conditional diffusion model with the primitive variables of flow fields for the compressible Taylor-Green vortex where the Reynolds number is less than or equivalent to 800, in addition to the inviscid flow field.

4. Results

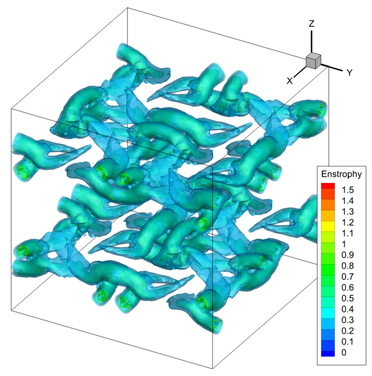


Fig. 1 Spatial distribution of enstrophy in a Taylor-Green vortex at Re=1,600 (t=50).

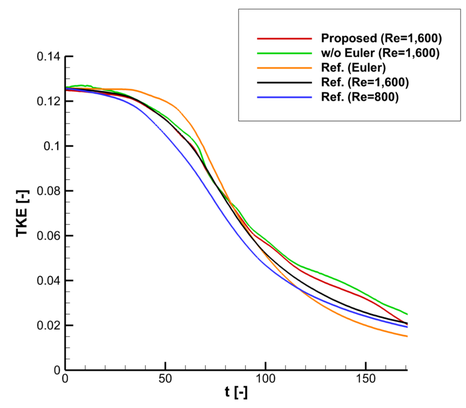


Fig. 2 Time evolution of total kinetic energy (TKE) in a Taylor-Green vortex.

5. Discussion and Future Works

- I aim to extending this work to general problems (i.e., diverse boundary conditions, initial conditions, and computational domain) with a single prior.

- I aim to reducing numerical diffusion when simulating inviscid flows by adopting e.g., KEEP schemes.

6. Conclusion

I have successfully confirmed the proposed method, which can predict and generate higer Reynolds number flows from lower Reynolds number flows, the inviscid flow, and the prior.

This research is partially supported by Initiative on Promotion of Supercomputing for Young or Women Researchers, Information Technology Center, The University of Tokyo.