MERIT Internship Report

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Outline

- Period
  October 11, 2022 — November 10, 2022
- Place
  Applied Materials Technology Center, Technology Division,
  Panasonic Holdings Corporation
- Theme
  Speeding up of fluid simulations using machine learning

Background and contents of the internship

Fluids are abundant in nature, and thus the prediction of fluid dynamics is of great importance in various fields of engineering. Fluid dynamics is described by the Navier-Stokes equations. However, the equations are difficult to calculate in the high-Reynolds-number regime where turbulence, the strongly nonlinear fluidic dynamics, appears. Thus, studies have proposed various numerical methods and models to simulate fluid dynamics, while they have problems in their accuracies and/or calculation costs for applicational use, and model-free high-speed methods are required.

On another front, machine-learning techniques have been improved by using neural networks that imitate biological brains and broadened their range of applications. Recent studies have proposed a neural-network technique to solve differential equations, which is called a physics-informed neural network (PINN). The PINN learns and constructs a neural network that outputs state variables (cf. the velocity of fluids) at arbitrary times and locations. Since PINN obtains the solutions of differential equations without direct numerical calculations, it can solve various equations quickly and accurately. Previous studies have also proposed PINNs to solve the Navier-Stokes equations, while their accuracy is lower than direct simulations.

In this internship, we improved the PINN algorithms and studied the high-speed and high-accuracy calculations of fluid dynamics. Specifically, we proposed the algorithm of automatic optimization of the hyperparameters that determine the weights of loss functions, and a modified method that introduces nonlinear terms to the input of the neural network. We confirmed the decrease in learning steps needed for the convergence of the learning results by using the proposed algorithms and found that the further-improved PINN can solve the Navier-Stokes equations quickly and accurately.

Impressions

In this internship, I learned how hydrodynamics and machine learning are used in device development. Through the study of machine learning toward actual applications, I also understood the issues and difficulties of applications of machine learning. Furthermore, I had many opportunities to talk with company members who study various themes and learned how the studies in universities are utilized in the studies in companies.

In addition, I learned the difference between the ways and purposes to study in companies and universities. I also broadened my horizons in the choice of careers, through the talks with company members who have various backgrounds. I believe that these experiences will be a great help both in my future studies at the university and my career choice.

Acknowledgments

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Reference

[1] Wandel, N., Weinmann, M., Neidlin, M., & Klein, R. (2022). Spline-PINN: Approaching PDEs without Data Using Fast, Physics-Informed Hermite-Spline CNNs. Proceedings of the AAAI Conference on Artificial Intelligence, 36(8), 8529-8538.