TU Clausthal

Neural Network-based Detection of Taylor Vortices in Annular Flow Systems

Exposé for Master Thesis - Initial Presentation

Mahyar Alikhani, Institute of Applied Mechanics
12. Dezember 2023

Contents

Problem Statement

Taylor-Couette flow

- a fluid dynamic phenomenon that occurs when a fluid is passing between two coaxial-rotating cylinders.
- Inner cylinder is typically rotating faster than outer cylinder.
- Dimensionless control parameters like Re, ω_{inner} and ω_{outter} are key factors

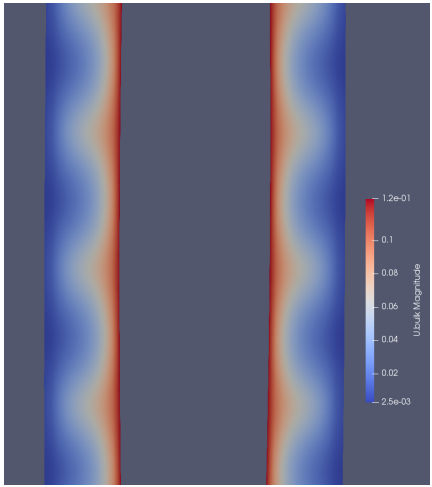


Abbildung: Taylor-couette vortices at time-step 200

Objectives

- Governing equ:

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla)\mathbf{u} = -\frac{1}{\rho}\nabla p + \nu \nabla^2 \mathbf{u} + \mathbf{f} \tag{1}$$

- w.r.t boundary conditions:

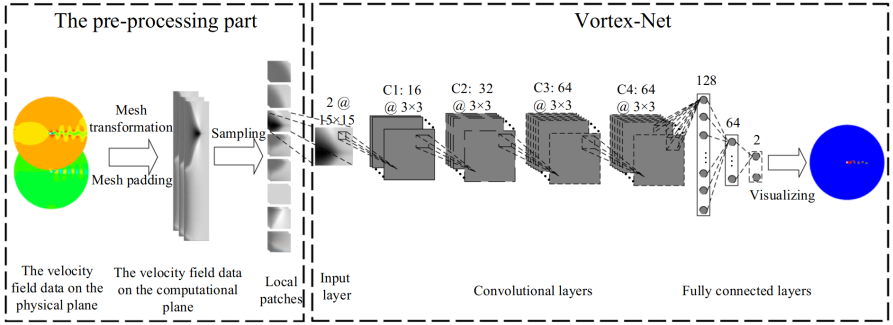
$$\mathbf{u} = \mathbf{u}_0 \quad \text{at} \quad \Gamma_1 \tag{2}$$

$$\mathbf{u} = 0 \quad \text{at} \quad \Gamma_2 \tag{3}$$

$$\frac{\partial p}{\partial n} = 0 \quad \text{at} \quad \Gamma_3 \tag{4}$$

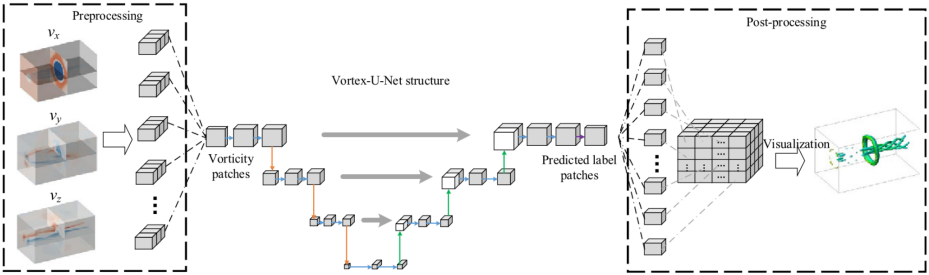
Litrature Review

(a) (Liang et al., 2018), a CNN-based vortex identification method to use both local and global information of flow field.



Litrature Review

(b) (Wang, Deng, Yang, Zhao & Wang, 2021), replacing the fully-connected NN with a segmented network to reduce the computational complexity.

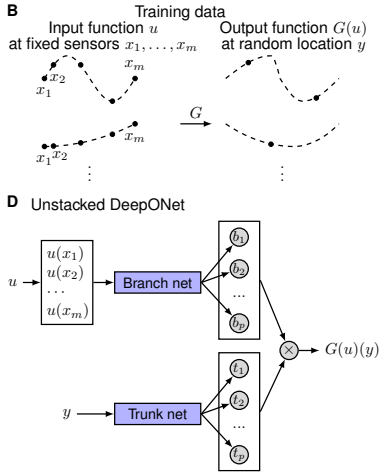


Approach

(a) Data preparation:

- running the *Taylor merve* case for different values of $\{\omega_{inner}, \omega_{outter}, Re\}$
- gathering the all data and

Deep operator networks(Lu, Jin, Pang, Zhang & Karniadakis, 2021) (DeepONets)



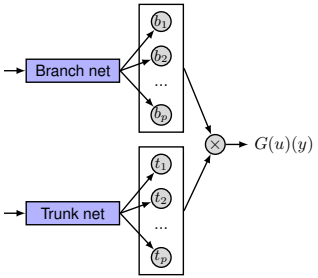
- Each input function u is evaluated at fixed sensor points $\{x_1, x_2, \ldots, x_m\}$
- y with d components and $u(x_i)$ for $i = 1, 2, \ldots, m$ are not matched. Therefor, it is needed to use two subnets. **Branch** for encoding input function at sensor points - **Trunk** for the location to evaluate output function

$$G(u)(y) \approx \sum_{k=1}^{p} b_k t_k + b_0 \qquad (5)$$

Deep operator networks (DeepONets): prediction of λ_2

Inputs of branch:
$\mathbf{u} \in \mathbb{R}^3$, $(N_s,\ 3)$
Outputs of branch:
$\boldsymbol{b} \in \mathbb{R}^{N_f}$, $(N_s,\ N_f)$

Inputs of trunk:
$\mathbf{X} \in \mathbb{R}^{128000}$, $(128000,\ 3)$
Outputs of trunk:
$\boldsymbol{t} \in \mathbb{R}^{N_f}$, $(128000,\ N_f)$



Outputs:
$\boldsymbol{u} \in \mathbb{R}^{1\times 128000}$,
$(N_s,\ N_f) \otimes (128000,\ N_f)^T$

Motivation

Timeline

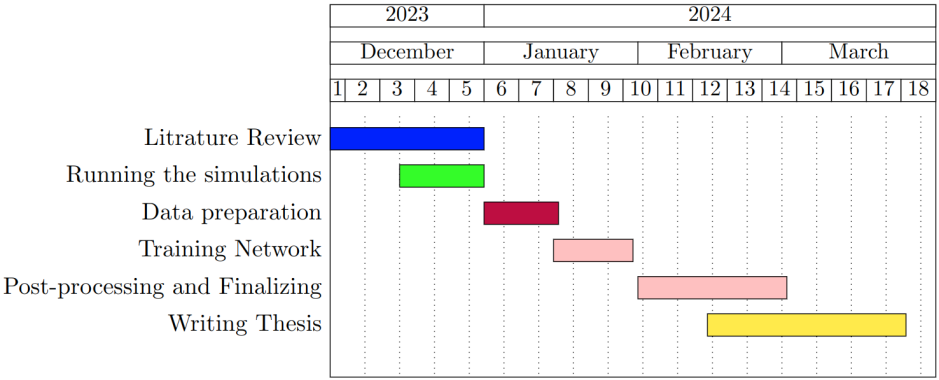


Abbildung: Timeplan

Thank you!

Any questions?

Liang, D., Wang, Y., Liu, Y., Wang, F., Li, S. & Liu, J. (2018, 10). A cnn-based vortex identification method. *Journal of Visualization*, *22*. doi: 10.1007/s12650-018-0523-1

Lu, L., Jin, P., Pang, G., Zhang, Z. & Karniadakis, G. E. (2021). Learning nonlinear operators via DeepONet based on the universal approximation theorem of operators. *Nature Machine Intelligence*, *3* (3), 218–229.

Wang, Y., Deng, L., Yang, Z., Zhao, D. & Wang, F. (2021, 01. Feb). A rapid vortex identification method using fully convolutional segmentation network. *The Visual Computer*, *37* (2), 261-273. Zugriff auf `https://doi.org/10.1007/s00371-020-01797-6` doi: 10.1007/s00371-020-01797-6