



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

Exposé for Master Thesis - Initial Presentation

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Contents

Problem Statment

Task definition and objective

Litrature Review

Approache

Time Planning

Literatur

Problem Statment

Taylor-Couette Flow

- It is defined as 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. This configuration can lead to various flow patterns and instabilities.
- Dimensionless control parameters like Re , ration of cylinder radii,

Objectives

- Governing equ:

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

- w.r.t boundary conditions:

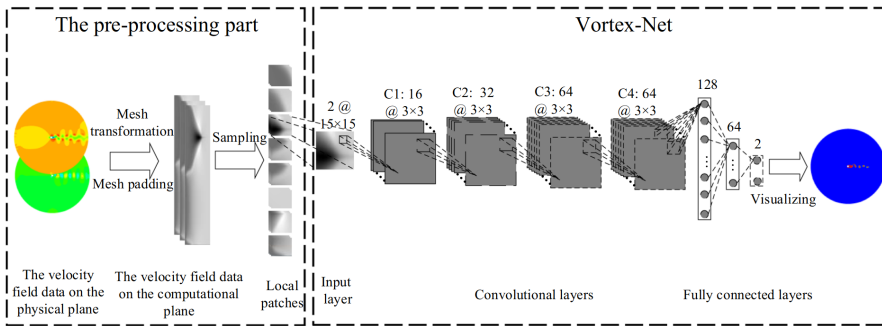
$$\mathbf{u} = \mathbf{u}_0 \quad \text{at} \quad \Gamma_1 \quad (2)$$

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

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

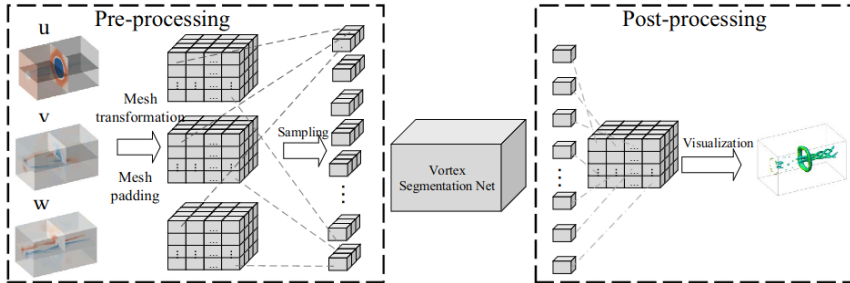
Literature Review

- (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.

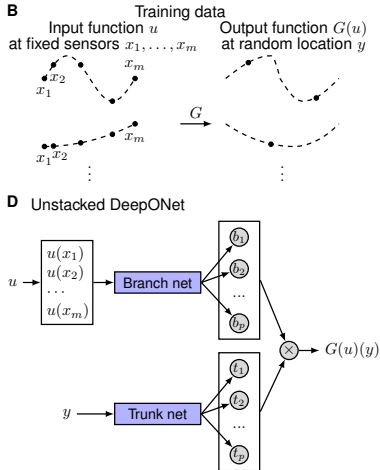




Approaches

- The

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



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

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

Deep operator networks (DeepONets): prediction of λ_2

Inputs of branch:

$$\mathbf{u} \in \mathbb{R}^3, (N_s, 3)$$

Outputs of branch:

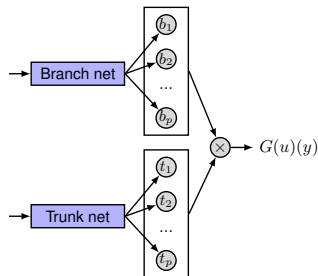
$$\mathbf{b} \in \mathbb{R}^{N_f}, (N_s, N_f)$$

Inputs of trunk:

$$\mathbf{X} \in \mathbb{R}^{128000}, (128000, 3)$$

Outputs of trunk:

$$\mathbf{t} \in \mathbb{R}^{N_f}, (128000, N_f)$$



Outputs:

$$\mathbf{u} \in \mathbb{R}^{1 \times 128000},$$

$$(N_s, N_f) \otimes (128000, N_f)^T$$



Timeline

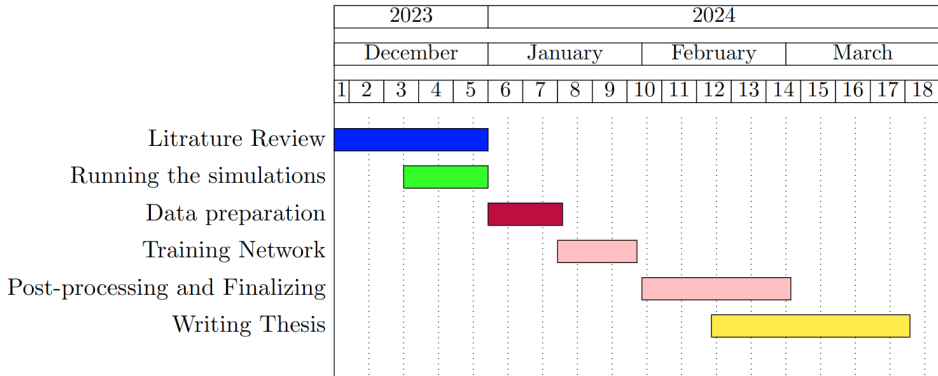


Abbildung: Timeplan



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