AI for Wind

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Science Meets Industry
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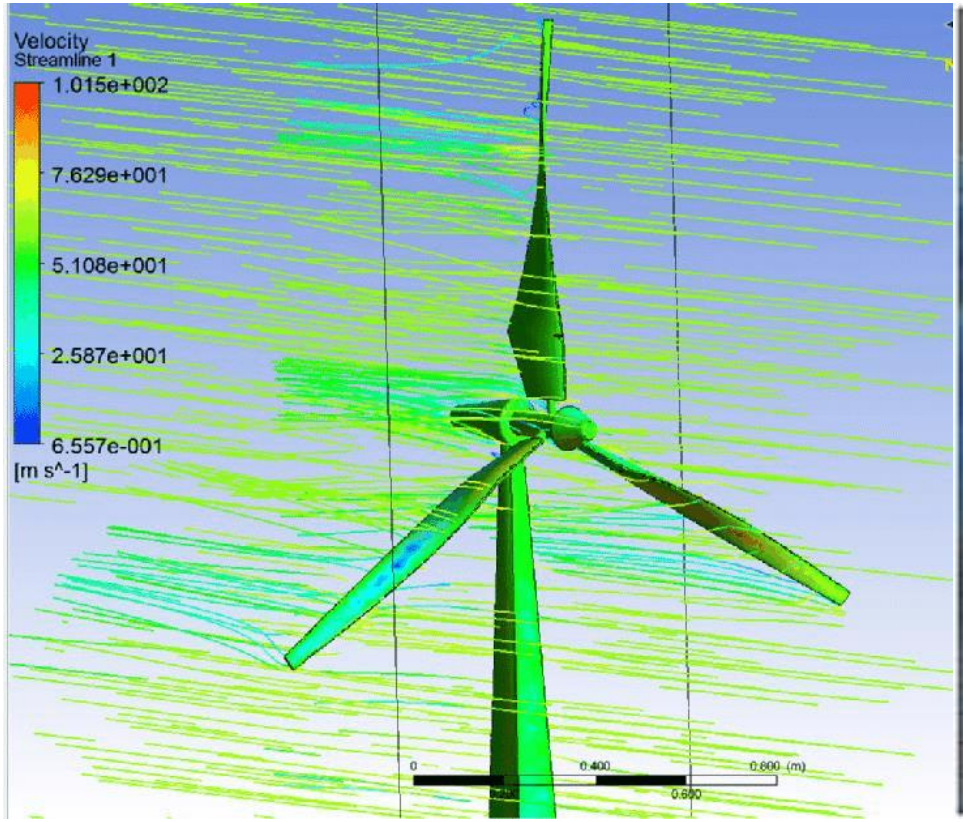
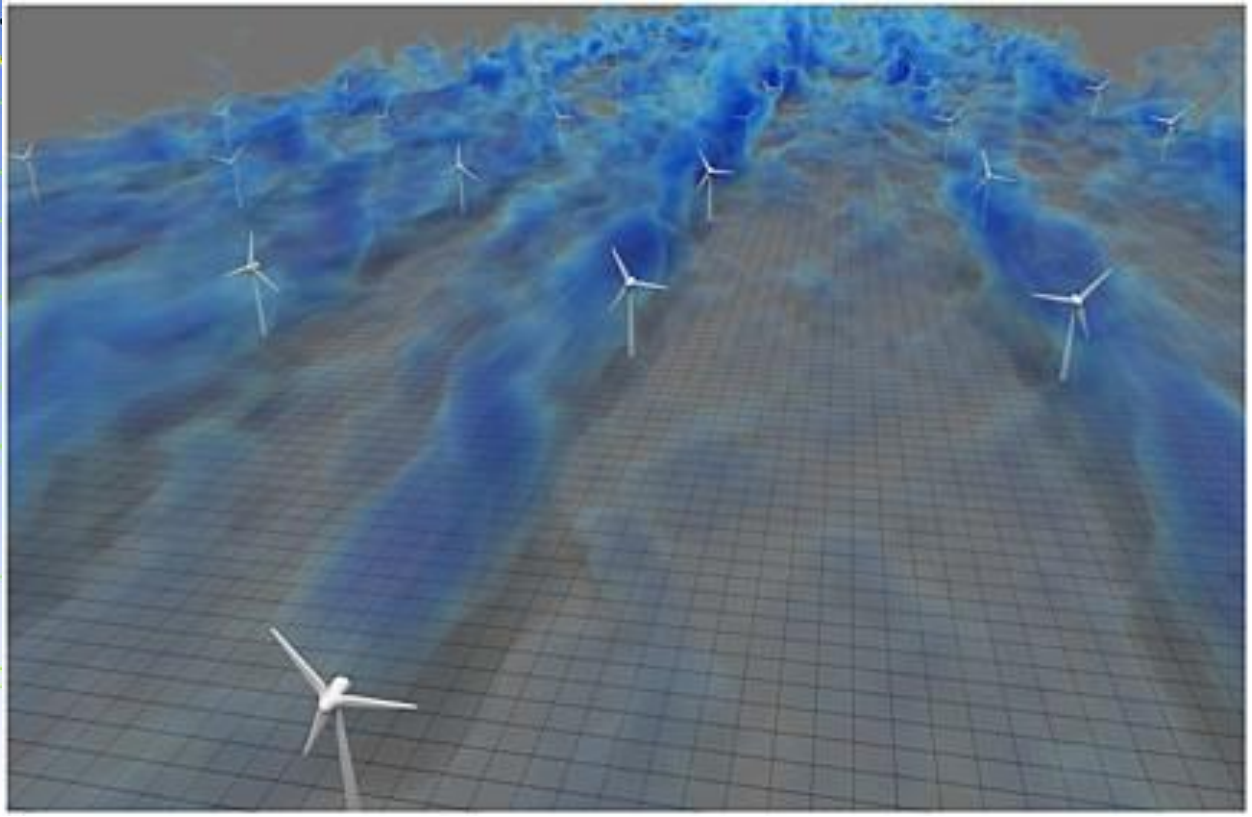
Simulate Wind and Fluid Using AI





FSI (Fluid Structure Interaction)

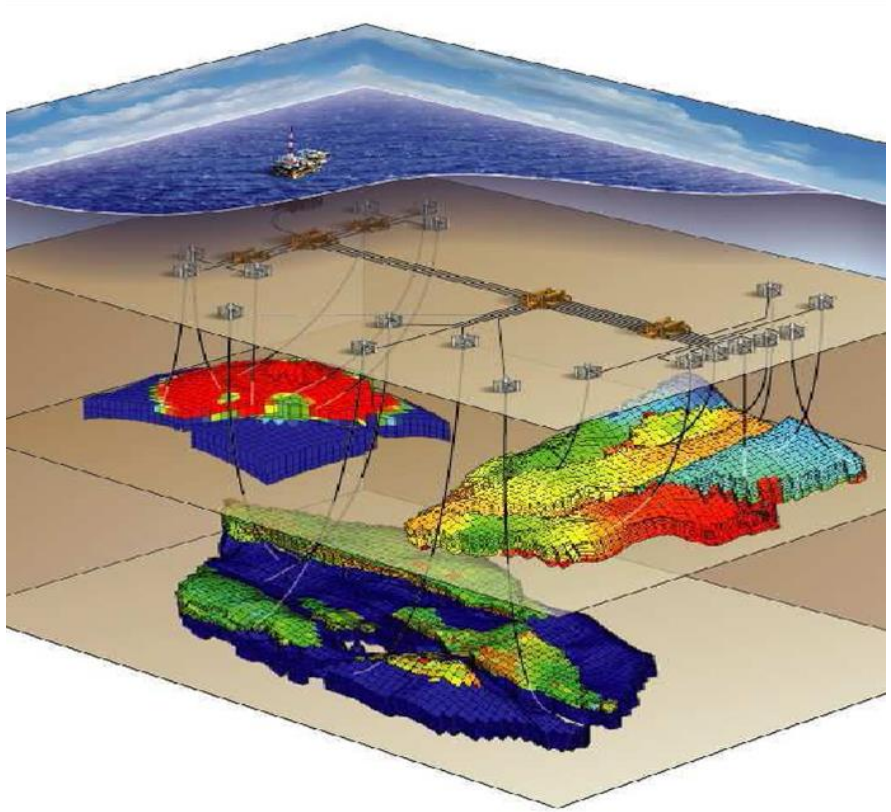
The turtle project (simula):
FSI (Fluid Structure Interaction)

Other Related Fluid Simulation Problems: Reservoirs and Ocean

The geometry for the reservoirs and Ocean can be complicated

The physical parameters need to be realistic

Simulate all possible scenarios



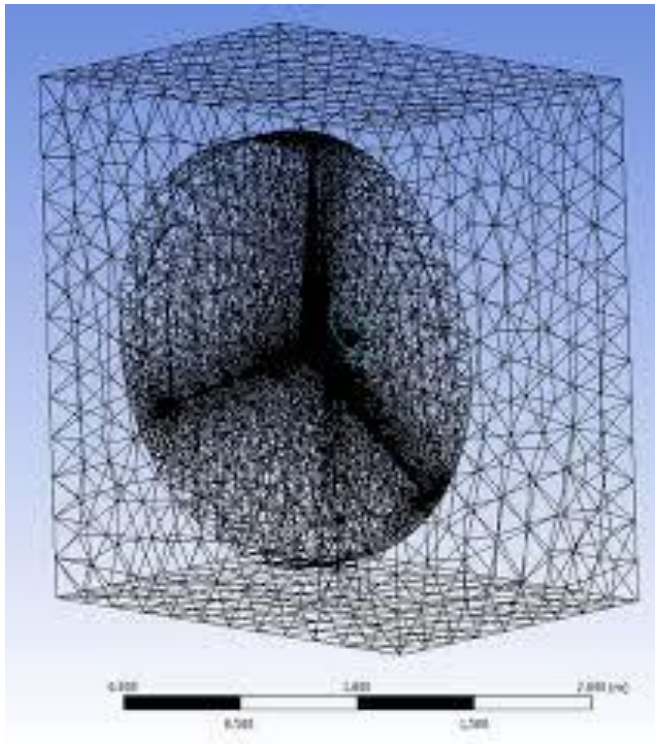
Our New Method:

- Meshless, good for complicated geometry
- Can handle high dimensions
- Can handle much large size problems

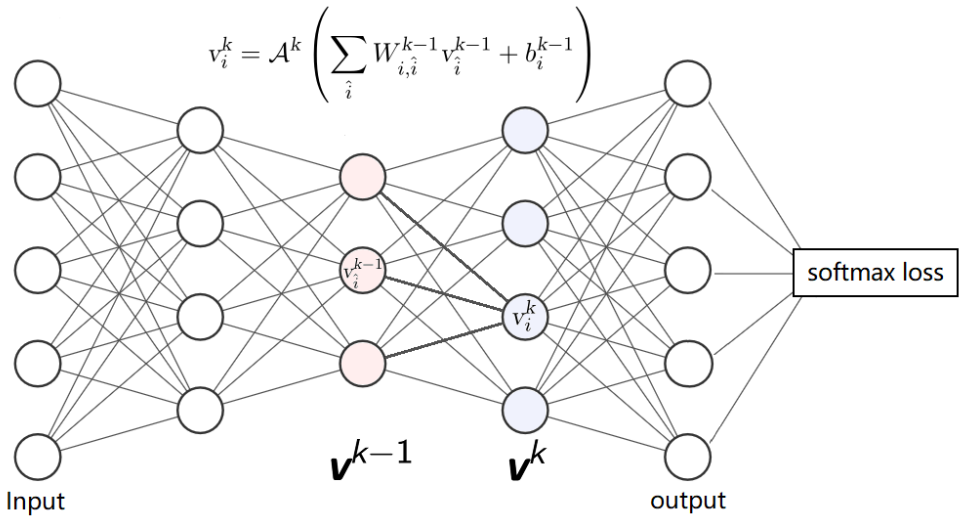
Traditional Fluid Simulations

Traditional Methods:

- Need to construct a mesh
- Mesh needs to move with time
- Interface moves with time
- Cannot handle high dimensions
- Cannot handle much large size problems



How to Use AI for Learning?



How to use Networks for learning like in ChatGPT?

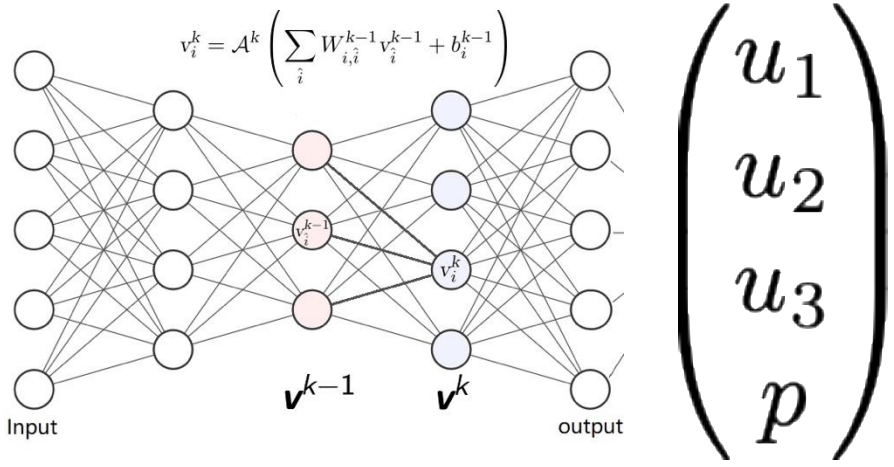
Input = a question (converted to vector of numbers)

Output = an answer (converted to vector of numbers)

A Neural Network is fitted to a huge number of available data, called network training.

How to Use AI for Fluid Simulations?

$$\begin{pmatrix} x \\ y \\ z \\ t \end{pmatrix}$$



$$\begin{pmatrix} u_1 \\ u_2 \\ u_3 \\ p \end{pmatrix}$$

Input = (x,y,z,t, parameters)
Output = (velocity, pressure)

Learn from data? No (or yes).

Learn from physical law: PINN
(physics-infomred Neural Networks)

$$\begin{cases} \rho_{\mathrm{f}} \dfrac{D\boldsymbol{u}}{Dt} + \rho_{\mathrm{f}}(\boldsymbol{u}-\boldsymbol{w}) \cdot \nabla \boldsymbol{u} - \nabla p = 0 \\ \nabla \cdot \boldsymbol{u} = 0 \end{cases} \quad \text{on} \quad \Omega_t^{\mathrm{f}}$$

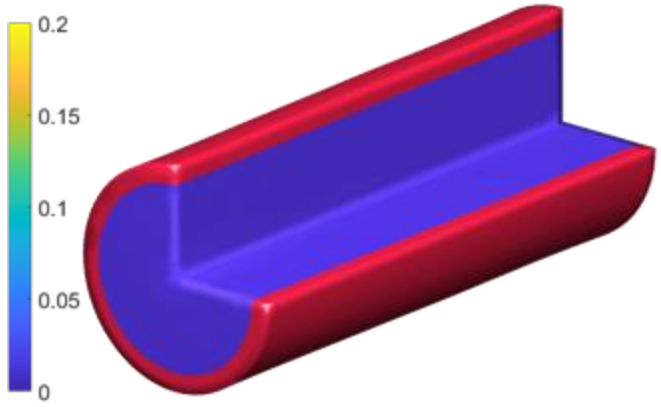
$$\begin{aligned} \boldsymbol{u} &= 0 && \text{on} \quad \Omega_0^{\mathrm{f}} \\ \boldsymbol{u} \circ \mathcal{A} &= \boldsymbol{w} && \text{on} \quad \Gamma_t^{\mathrm{w}} \\ \boldsymbol{u} &= \left(1 - \frac{y^2}{r_0^2}\right)\boldsymbol{g} && \text{on} \quad \Gamma_t^{\mathrm{in}} \\ \boldsymbol{\sigma}_{\mathrm{f}} \cdot \boldsymbol{n} &= 0 && \text{on} \quad \Gamma_t^{\mathrm{out}} \end{aligned}$$

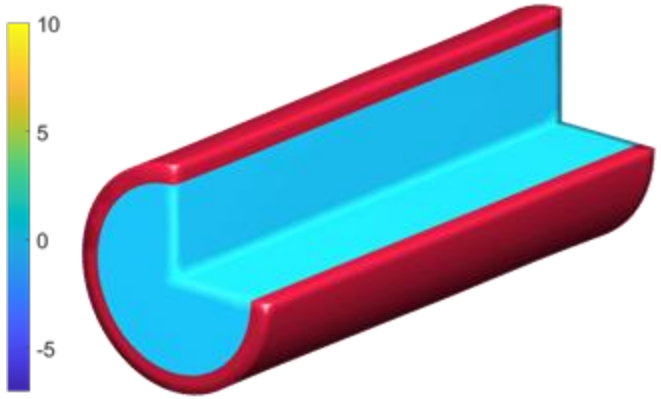
Video Visualization

Velocity Magnitude

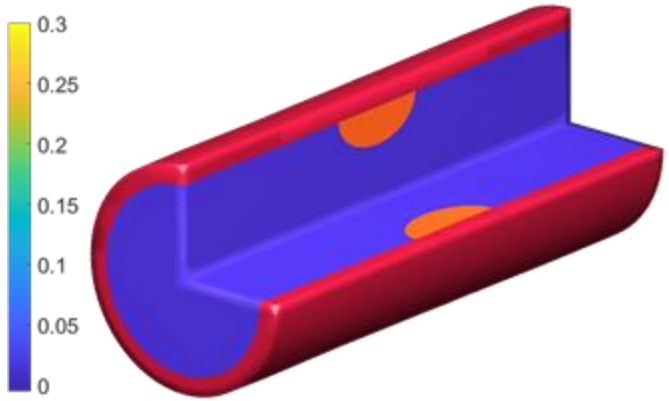
Pressure Magnitude

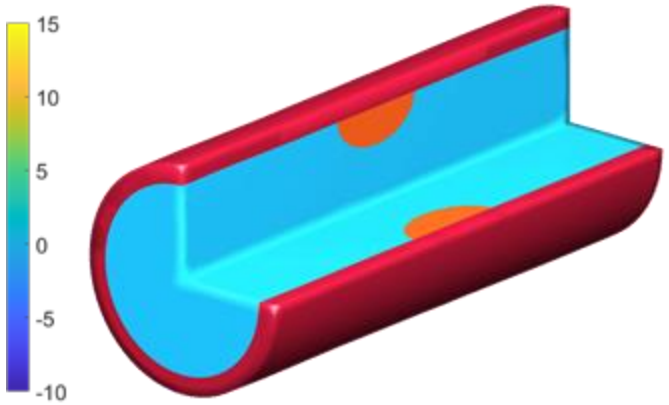
Cylinder Vessel





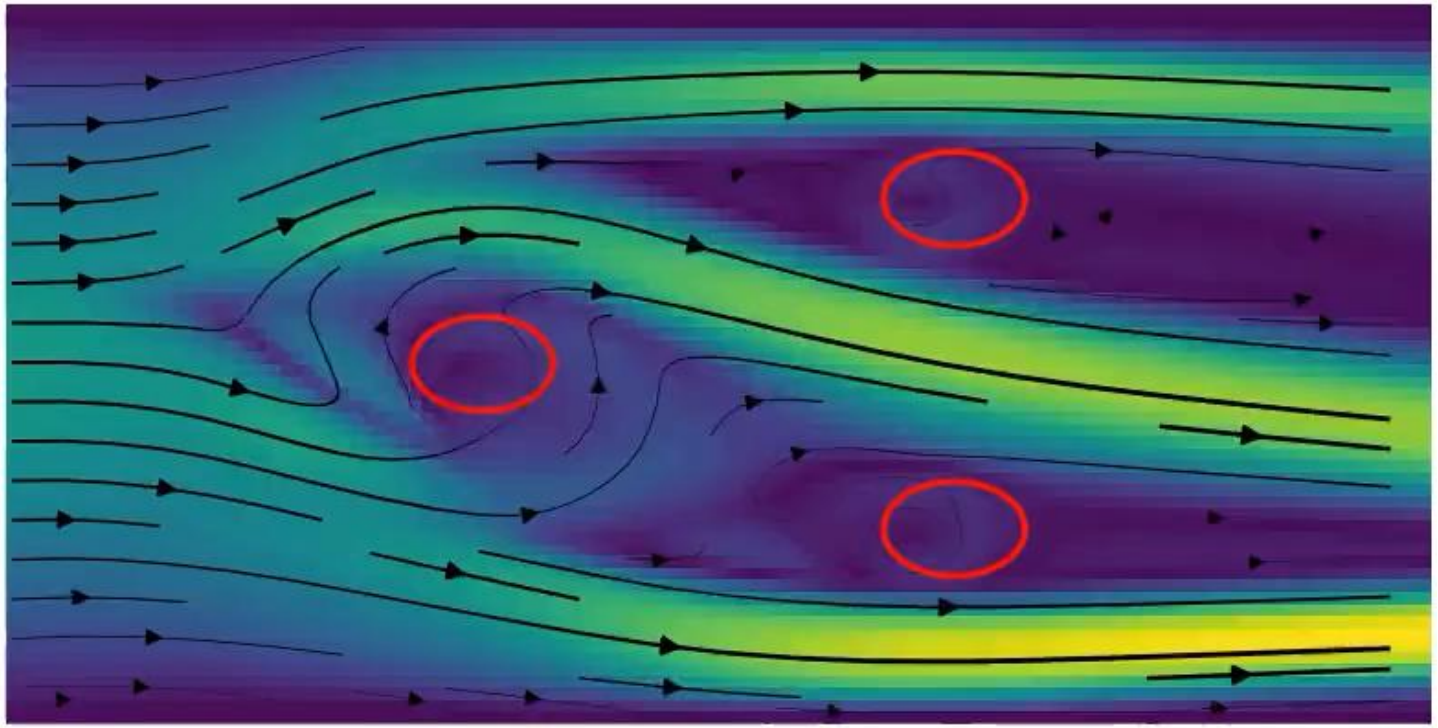
Plaqued Vessel





Zhang, H., Chan, R. H., & Tai, X. C. (2024). a Meshless Solver for Blood Flow Simulations in Elastic Vessels Using a Physics-Informed Neural Network. *SIAM Journal on Scientific Computing*, *46*(4), C479–C507. https://doi.org/10.1137/23M1622696

AI for Wind (a demo)



(red objects represent moving obstacles, for example wind turbines.)

This is a in-house demo for using PINN + DNNs for wind simulations.

Welcome
Collaborations and joint efforts to develop these methods.

Thank you. Takk. Merci. Gracias. Obrigado.

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