Machine learning to unveil the fluid-structure interaction of air-backed impact

NYU Summer Research Program

May 24th 2021 to July 30th 2021

Hypothesis

- Machine learning will help us understand complex fluid-structure interactions that might be hidden in classical analysis
- Machine learning tools will predict the fluid-structure interactions of impactors with different shapes and speeds
    - Velocity field
    - Dynamic loading on the panel
    - Structural dynamic on the panel

Deliverable I

- Initially, a neural network will be constructed using TensorFlow to create masks for PIV images of the impact experiments
    - This neural network will learn from manually masked images from PIV analysis
    - This neural network will be able to automatically mask images for PIV analysis over a range of impactor shapes and speeds

Deliverable II

- The neural network will also learn the fluid-structure interaction in terms of velocity field and structural dynamics (deformation of mask associated with the panel).
    - The neural network will learn to compute the velocity field from 6 previous PIV analysis (Peng's prior work) for a given impact speed and impactor shape. The neural network will be trained through a physics-based training. 25% of the available data will be used for testing the accuracy of the neural network
    - *In a further step, we will develop another neural network that will learn to compute deformation of resolved masks in the region of the panel, allowing to account for the structural dynamics. DIC and PIV datasets will be used as inputs for this purpose to increase the accuracy**
    - *As an end-goal, the neural networks will be able to compute the velocity field and structural dynamics for an impact test**

Timeline

Week	Task
1-2 (May 24th)	Literature review of Machine Learning techniques in FSI and wrap up of prior work. Prepare a presentation with the findings and propose a ML physics-based model that will be implemented for flow field prediction. Set up GPU station, Tensorflow
2	Prepare a large dataset of ground truth masked images. Manual masking of 6 datasets. Perform augmentation techniques to increase the size of the datasets (rotations, magnification)
3	Development of a neural network for PIV masking. Perform parametric analysis on the neural network parameters (batch size, number of filters, drop-out, number of hidden layers, activation function, loss function, epoch number). Import predicted mask to PIVLab and demonstrate a successful PIV analysis with predicted masks

Timeline

Week	Task
4-8 (June 21st)	Development of a physics-based neural network to learn the velocity field from PIV analysis. In this step, the ground truth data will be the velocity field from the PIV analysis. Perform parametric analysis on the neural network parameters (batch size, number of filters, drop-out, number of hidden layers, activation function, loss function, epoch number).
9-10	Testing and validation of the neural network in the prediction of the velocity field

From Simon's side

Week	Task
1-2 (May 24th)	Provide a range of research articles. Brainstorm for ML approaches to infer flow physics. Training of the student in PIVLab analysis if needed.
3-5	Complete experiments with different shapes/velocities if they are not done yet.
6-8 (June 28th)	Work on physics-based model for ML flow

Relevant references

Topic	Reference
Deep Learning	
Fully Connected Neural Networks	
Convolutional Neural Networks	