MEng Project 1

Uncertainty-Aware Pressure Reconstruction from Noisy PIV Data

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Project objective and research question. This project will develop and evaluate a computational workflow for recovering pressure from time-resolved or phase-resolved particle-image-velocimetry (PIV) measurements of unsteady separated flows. The central research question is: under what levels of measurement noise, temporal sparsity, and missing vectors do physics-informed methods provide a meaningful improvement over conventional pressure-Poisson reconstruction and ordinary smoothing? The scope emphasizes quantified uncertainty and generalization to archived separated-flow measurements rather than a single ideal benchmark.

Engineering-science foundation. The work applies conservation of mass and momentum, the incompressible Navier-Stokes equations, pressure gradients, vorticity, numerical differentiation, inverse problems, uncertainty propagation, and statistical validation. It connects experimental fluid mechanics with scientific machine learning.

Methodology, data, and scope. The student will first reproduce a conventional pressure-Poisson baseline on a synthetic flow with known pressure. Controlled noise, reduced frame rate, spatial masking, and missing-vector tests will then be introduced. A physics-informed neural network or related differentiable model will reconstruct velocity and pressure while enforcing continuity and momentum residuals. The best-performing workflow will be applied to an archived PIV dataset for an unsteady airfoil or synthetic-jet flow. Python, OpenPIV-compatible data, PyTorch, and a GPU workstation or cluster will be used. Suitable preparation includes fluid mechanics, numerical methods, and Python; prior machine-learning experience is helpful but not required.

Success metrics and contingency. Pressure correlation and relative RMS error; pressure-gradient error; continuity and momentum residuals; sensitivity to noise and temporal spacing; and computational cost. If full physics-informed training is unstable, the minimum viable project will compare conventional reconstruction with temporal denoising and a reduced physics-constrained network on one flow condition.

Two-Term Work Plan and Deliverables

Term	Planned productive work	Deliverable due by the last day of lectures
1	Literature review and study design (20 h); establish synthetic benchmark and conventional baseline (35 h); implement controlled noise and sparsity tests (25 h); develop initial physics-informed model (45 h); document methods and results (15 h). Total: 140 h.	Interim technical report, verified baseline, and reproducible code with initial benchmark results.
2	Complete model and sensitivity study (50 h); apply workflow to archived PIV data (35 h); quantify uncertainty and compare methods (30 h); prepare figures and reproducible package (15 h); final report and presentation (20 h). Total: 150 h.	Final engineering report, complete repository and results package, and oral or poster presentation.

Expected outcome. A defensible map of when physics-informed pressure reconstruction is useful, together with a reusable workflow for noisy experimental velocity fields.