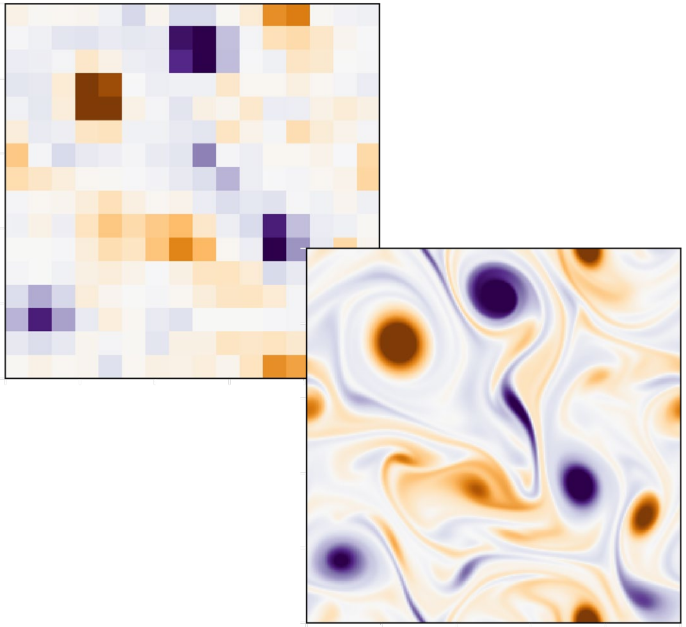
UCLA Samueli Mechanical & Aerospace Engineering

Developing artificial-intelligent techniques for turbulence



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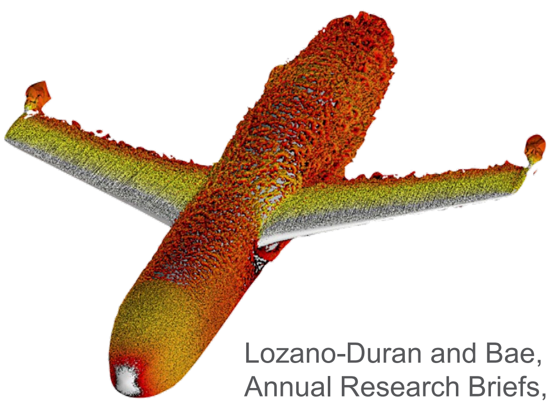
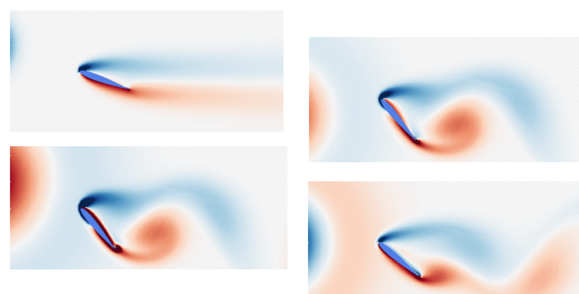
Turbulent flow reconstruction

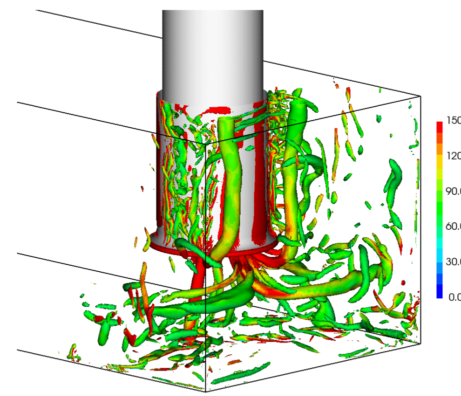
- Gaining situational awareness of fluid flows from limited measurements has been a challenging issue
  - Useful for controlling and understanding fluid flows
    - Automobile, airplane, fluid-based machines
- We are capable of computationally and experimentally measuring complex flow fields
- Extraordinal development of computational and experimental resources



Lozano-Duran and Bae, Annual Research Briefs, CTR, Stanford University, 2020



Fukami and Taira, NeurIPS2022



Liu et al., J. Fluids Eng., 2020

- Can we leverage **machine learning** techniques for fluid flow reconstruction?

Super-resolution analysis

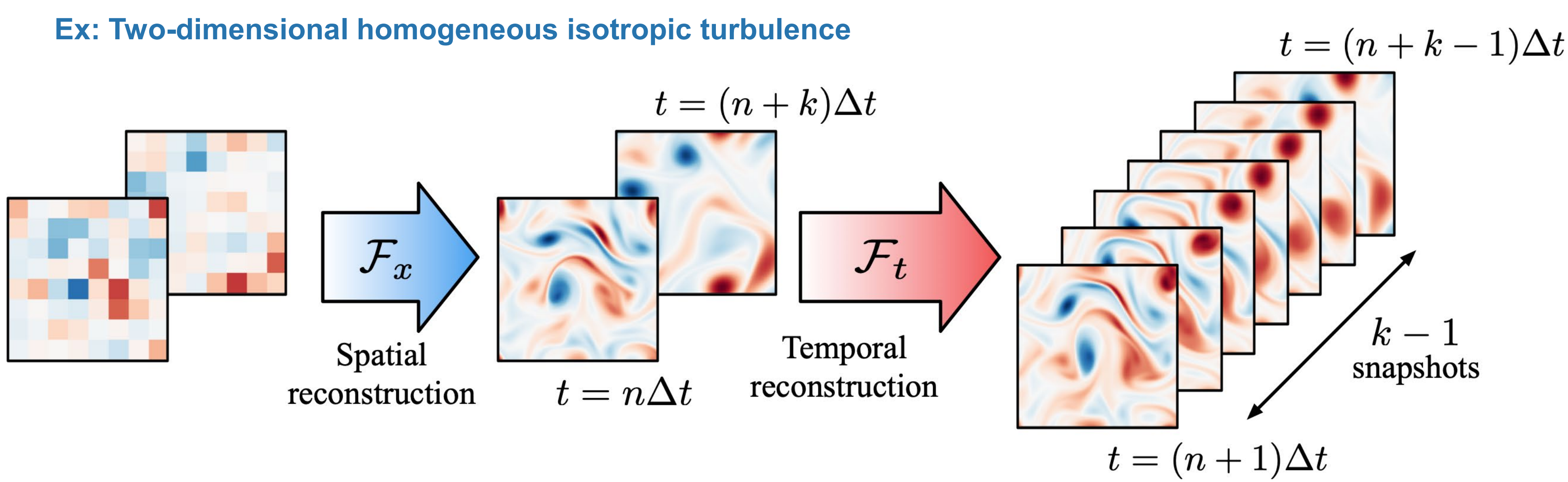
$$\boldsymbol{q}_{\mathrm{HR}} = F(\boldsymbol{q}_{\mathrm{LR}})$$

- One of the reconstruction methods in the image tasks
- Reconstructs high-resolution (HR) signal from low-resolution (LR) signal

Irani & Peleg, Graphical models and image processing, 1991
Romano et al., IEEE Trans. Comput. Imaging, 2017

Machine-learning-based super resolution x Fluid flows

- We have been working on supervised-learning-based super-resolution analysis of turbulent vortical flows.



$$\boldsymbol{q}(x_{\mathrm{HR}}, t_{\mathrm{HR}}) = \mathcal{F}_t(\mathcal{F}_x^*(\boldsymbol{q}(x_{\mathrm{LR}}, t_{\mathrm{LR}})))$$

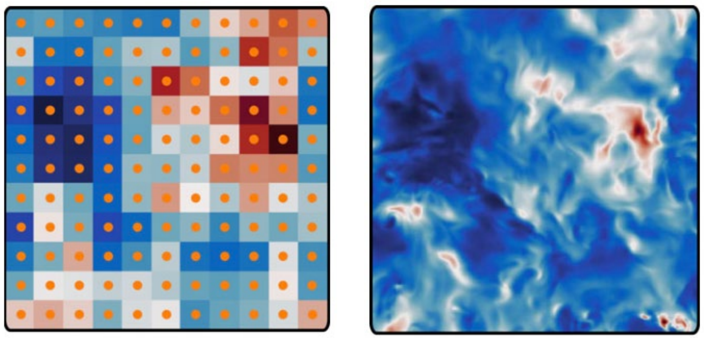
- Super resolution in space and inbetweening in time
- The idea can be extended to sparse sensor measurements
- Special care is needed for the construction of neural networks to account for multi length scales

Fukami, Fukagata, Taira, J. Fluid Mech., 2019, 2021
Fukami et al., Nature Machine Intelligence, 2021

Machine-learning-based super resolution x Fluid flows

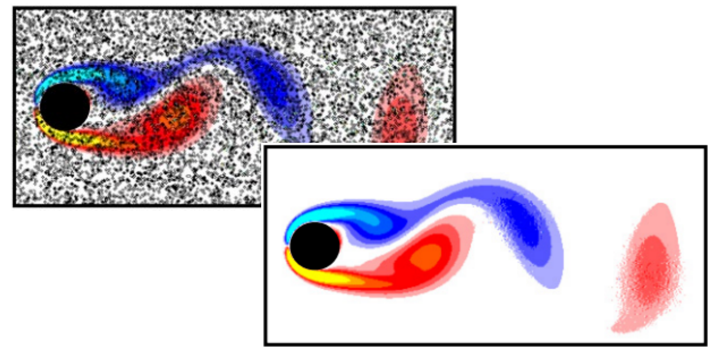
- A general framework for a broad range of applications in fluid mechanics

Sparse sensor reconstruction



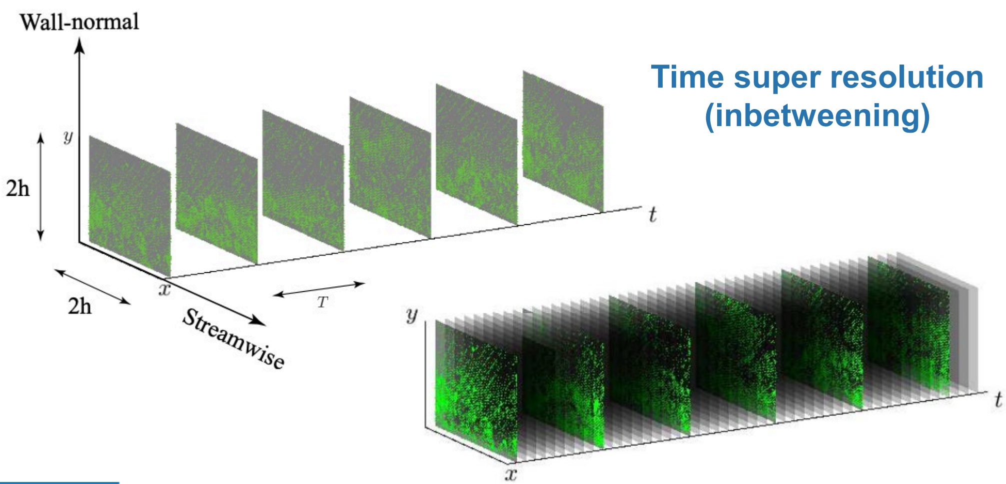
Erichson et al., Proc. Roy. Soc. A., 2020

Denoising / Noise removal



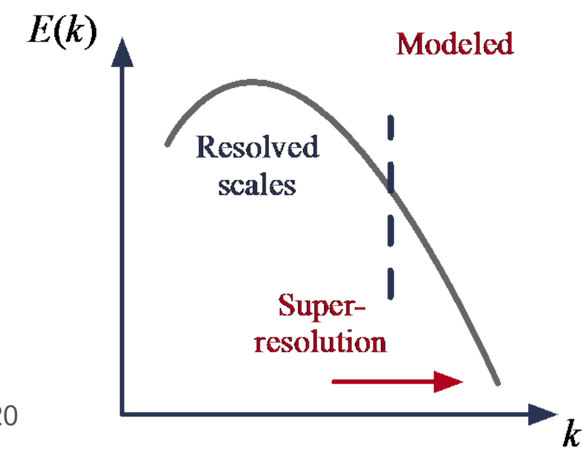
Scherl et al., Phys. Rev. Fluids, 2020

Time super resolution (inbetweening)



Vamsi Krishna et al., Phys. Rev. Fluids, 2020

Turbulence modeling



Maulik and San, J. Fluid Mech., 2017

Machine-learning-based super resolution x Fluid flows

- Surveys the recent studies for machine-learning-based super-resolution analysis for fluid flows

SUPER-RESOLUTION ANALYSIS VIA MACHINE LEARNING: A SURVEY FOR FLUID FLOWS

A PREPRINT

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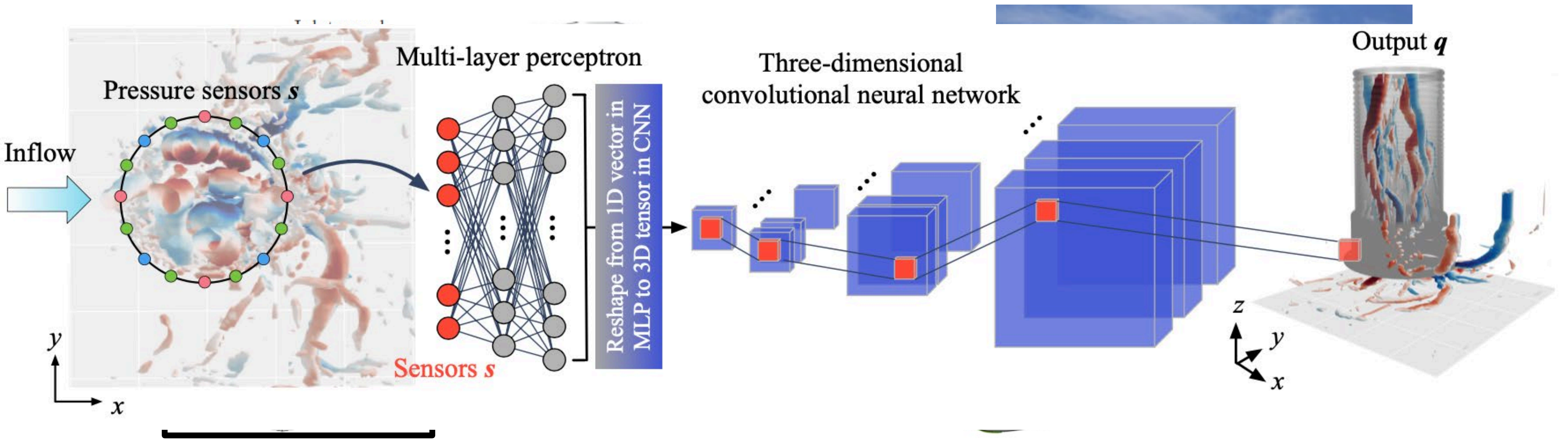
ABSTRACT

This paper surveys machine-learning-based super-resolution reconstruction for vortical flows. Super resolution aims to find the high-resolution flow fields from low-resolution data and is generally an approach used in image reconstruction. In addition to surveying a variety of recent super-resolution applications, we provide case studies of super-resolution analysis for an example of two-dimensional decaying isotropic turbulence. We demonstrate that physics-inspired model designs enable successful reconstruction of vortical flows from spatially limited measurements. We also discuss the challenges and outlooks of machine-learning-based super-resolution analysis for fluid flow applications. The insights gained from this study can be leveraged for super-resolution analysis of numerical and experimental flow data.

Ongoing studies for practical scenes

- Applications to turbulent flows around industrial fluid-based machines and airplanes



Fukami et al., J. Fluids Eng., 2022

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Welcome your feedback!

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