Turbulent Flow Prediction from Wall Measurements Using Generative Models

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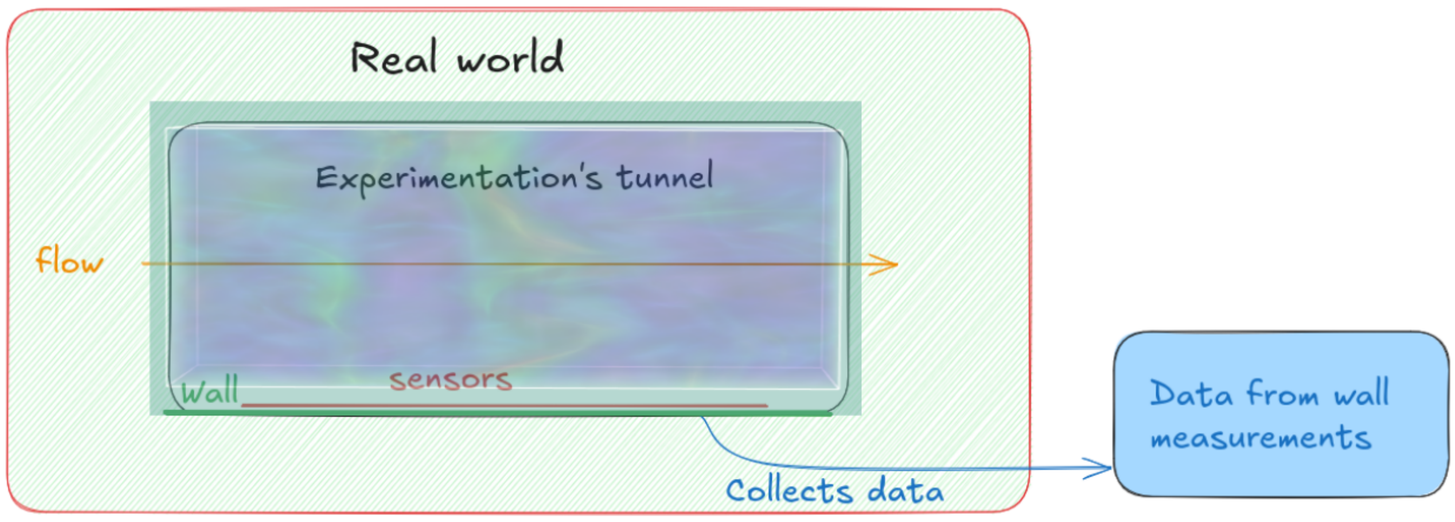
Computer Science

HPC & Data Science

Paper's context (2D view, real context is 3D)



Subject

Context: Predicting turbulent flows from wall-based measurements is a promising direction for flow control and optimization in aerospace and mechanical engineering.

Approach: I used a GAN-based architecture (generator + discriminator) trained on channel flow data, aiming to reconstruct velocity fields (u, v, w) inside the channel from limited wall sensors.

Summary of Activities

Over a five-month supervised research project, I:

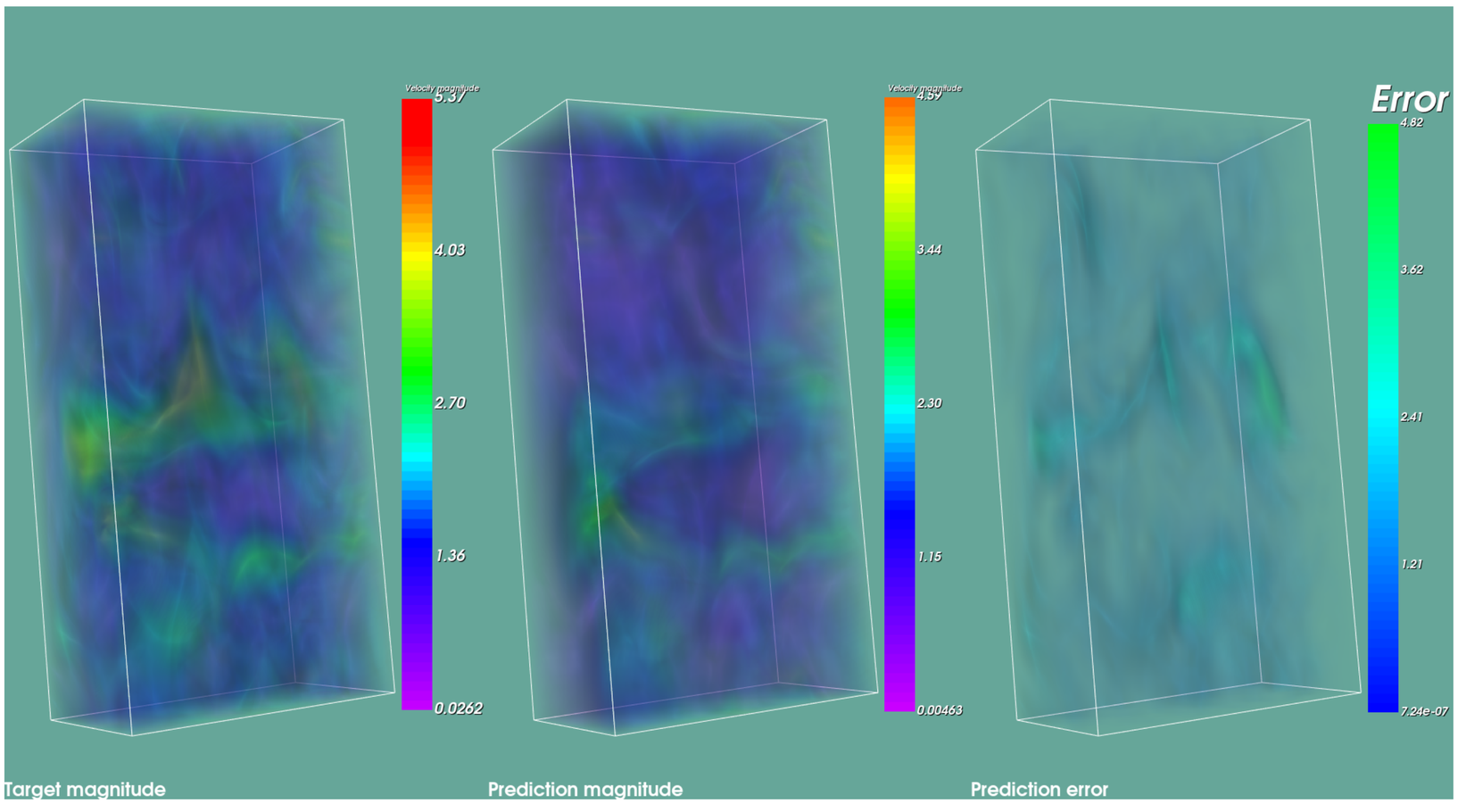
- Built a complete working environment for training/testing models.
- Replicated results from a reference paper on turbulent flow prediction.
- Explored improvements by tuning inputs, normalization, and discriminator balance.
- Evaluated how each modification affected accuracy across the channel.

Problematic and Context

Turbulent flows contain multi-scale structures that are hard to capture.

Near-wall regions are particularly difficult to predict due to strong gradients.

Previous approaches showed promise but had limited accuracy far from the wall.



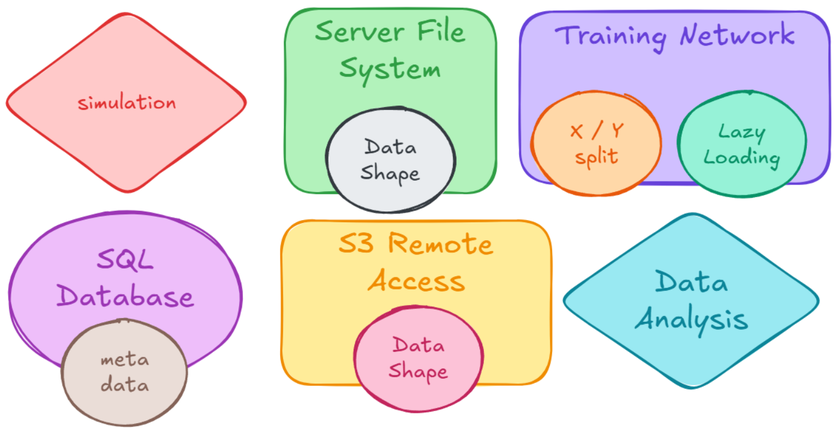


Figure: The different components of the working environment I setup.

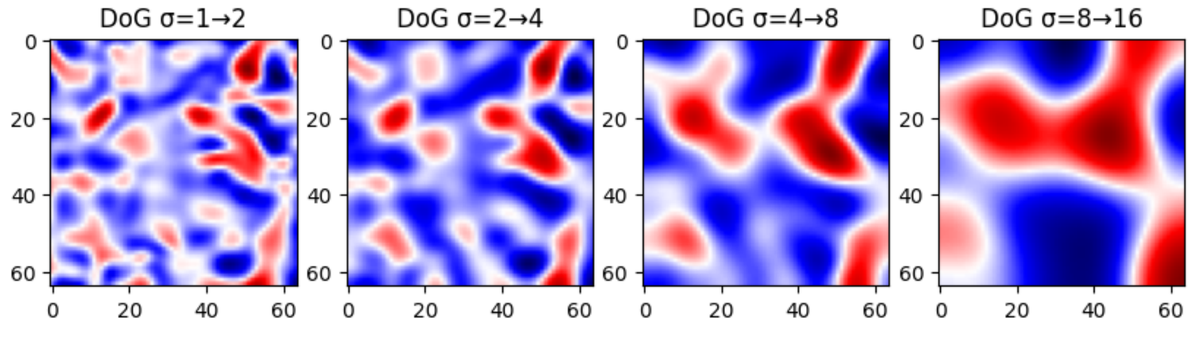


Figure: Illustration of the effect of scale filtering: wide patterns are extracted from noisy inputs.

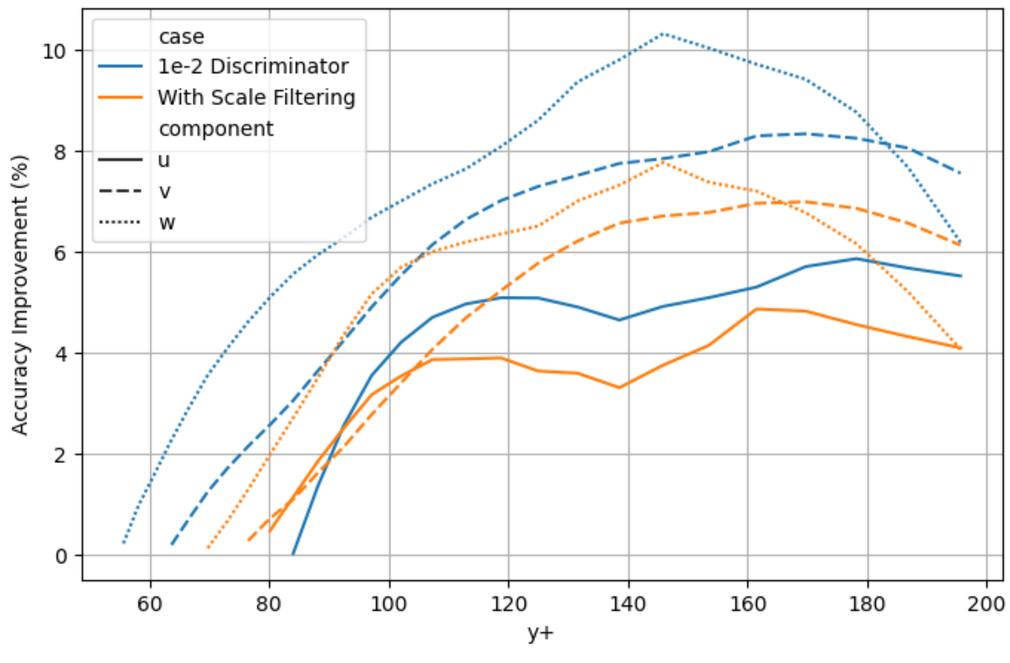


Figure: Prediction improvement over the wall-normal axis (y-axis).

Solving the Problem

I experimented with:

- Input filtering to scale-select wall signals.
- Normalization strategies to stabilize training.
- Tuning discriminator influence to guide generator learning.

Key findings

Improvements were seen at the far-end of the channel (up to 10% for component w).
However, near-wall accuracy decreased when focusing on far-end gains.

Conclusion and Perspectives

My study clarifies the trade-off between near-wall and far-channel prediction accuracy. Refinements in discriminator balance and input scaling help, but major architectural changes may be required.