

Physics-Informed Neural Operators for Aerodynamic Surrogate Modeling: Enhancing Generalization and Robustness in Aircraft Flow Prediction

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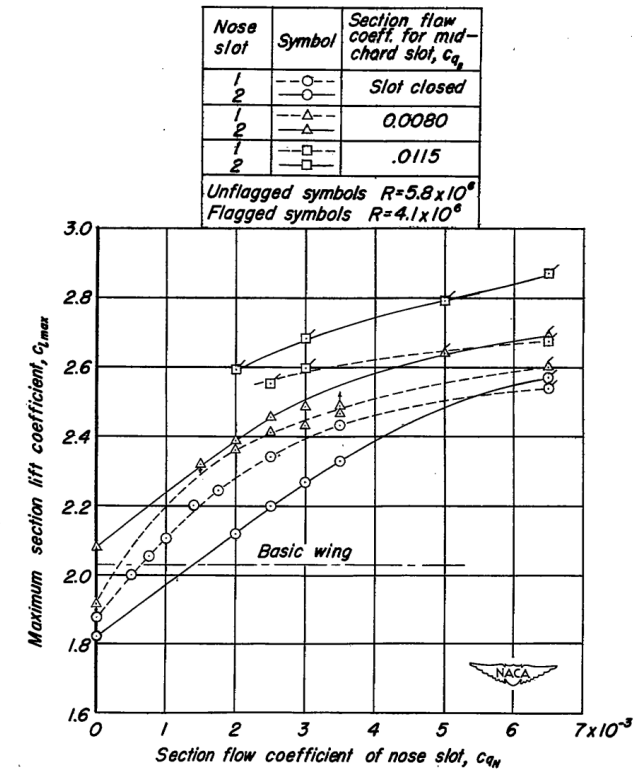
PhD Aerospace Engineering UC3M

Doctoral Meetings 2026

2nd and 3rd June 2026

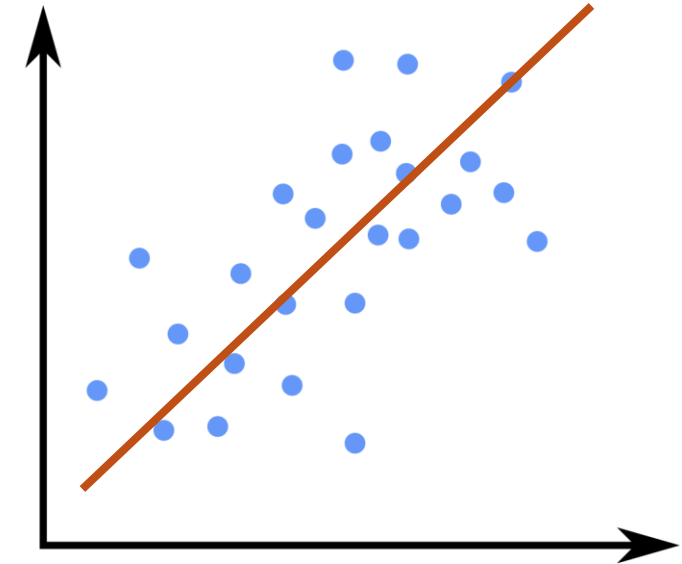
The vicious cycle of data scarcity, model complexity, and cost

- Expensive data
- Reduced computing power
- Simple models



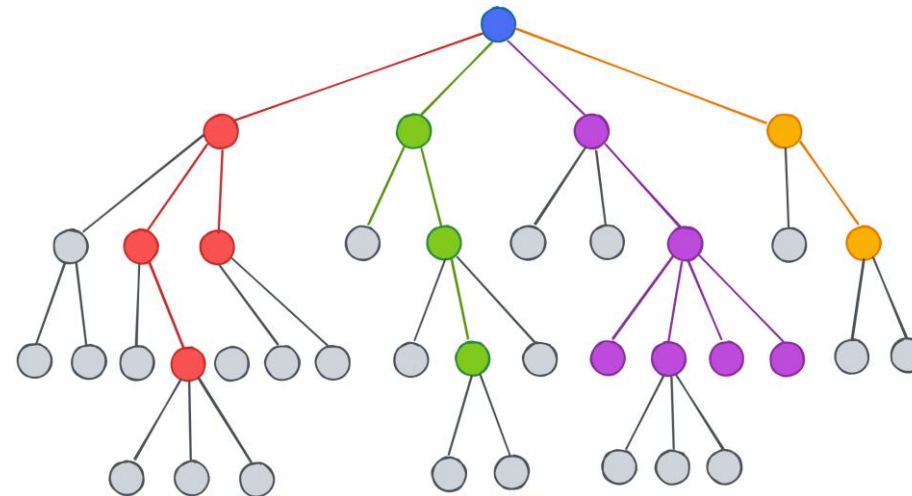
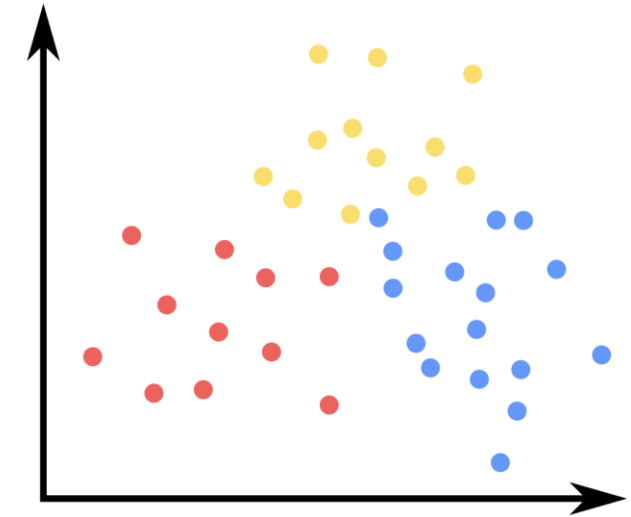
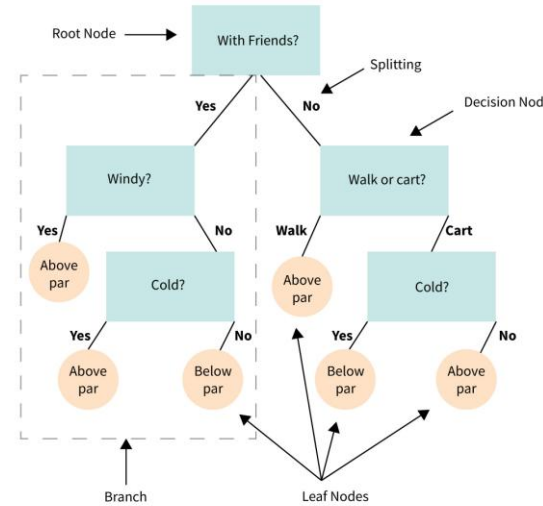
The vicious cycle of data scarcity, model complexity, and cost

- Expensive data
- Reduced computing power
- Simple models



The vicious cycle of data scarcity, model complexity, and cost

- Computers appear!
 - Cheaper data
 - More complex algorithms

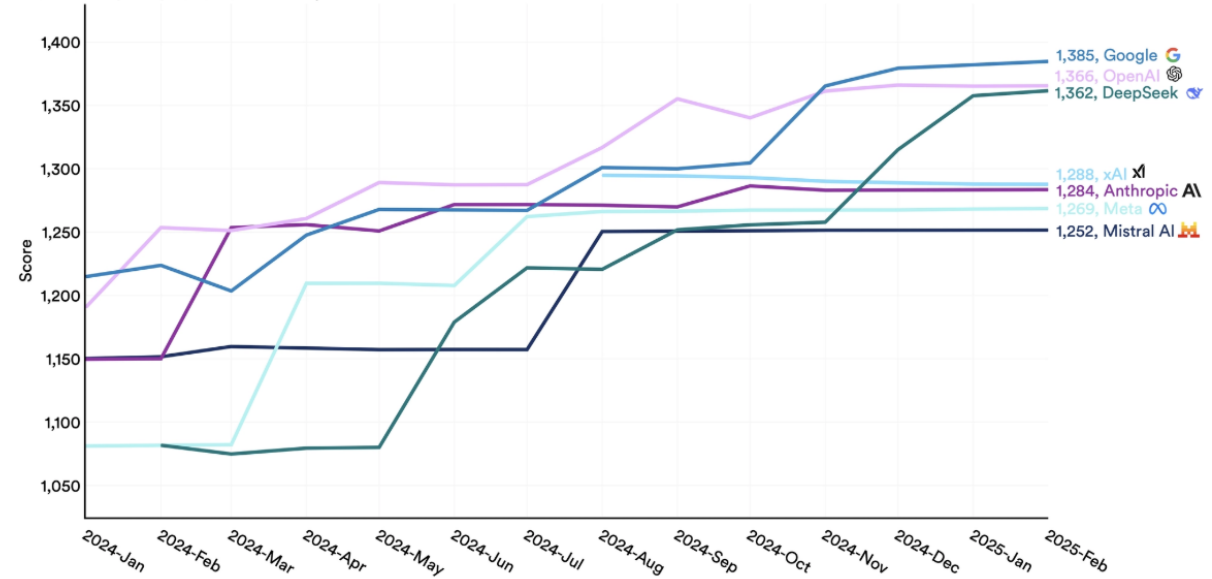


The vicious cycle of data scarcity, model complexity, and cost

- Training time
 - doubled every ~5 months
- Dataset size
 - doubled every 8 months
- Power consumption
 - 5x/year since 2020

Performance of top models on LMSYS Chatbot Arena by select providers

Source: LMSYS, 2025 | Chart: 2025 AI Index report



Smallest AI models scoring above 60% on MMLU, 2022–24

Source: Abdin et al., 2024 | Chart: 2025 AI Index report



[1] Stanford 2025 AI Index report

The vicious cycle of data scarcity, model complexity, and cost

- Training time

- doubled every ~5 months

- Data

-

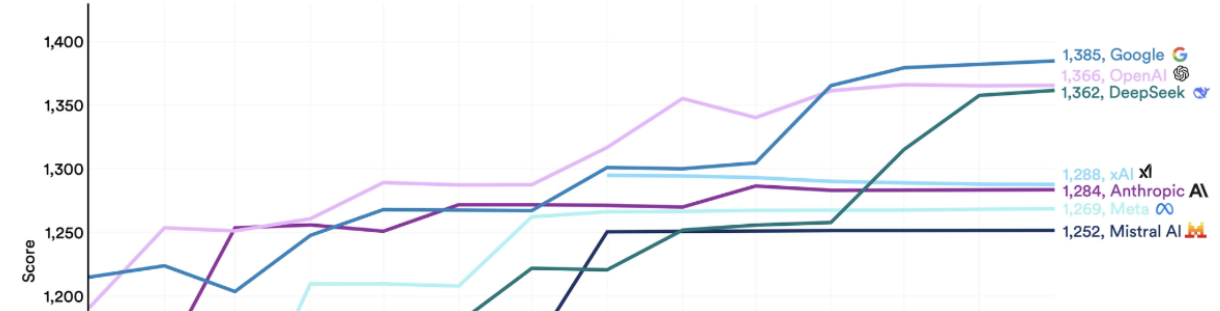
- Power

- 5x/year since 2020

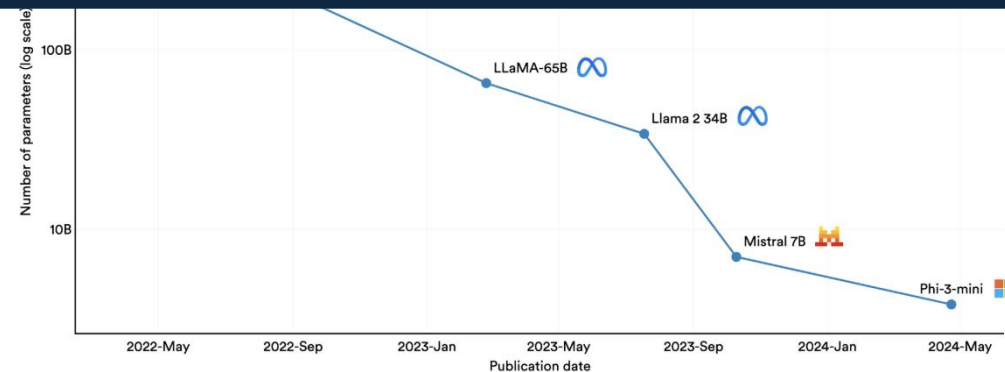
[1] Stanford 2025 AI Index report

Performance of top models on LMSYS Chatbot Arena by select providers

Source: LMSYS, 2025 | Chart: 2025 AI Index report



As always is to do **more** with **less**



Thesis scope: Doing more with less

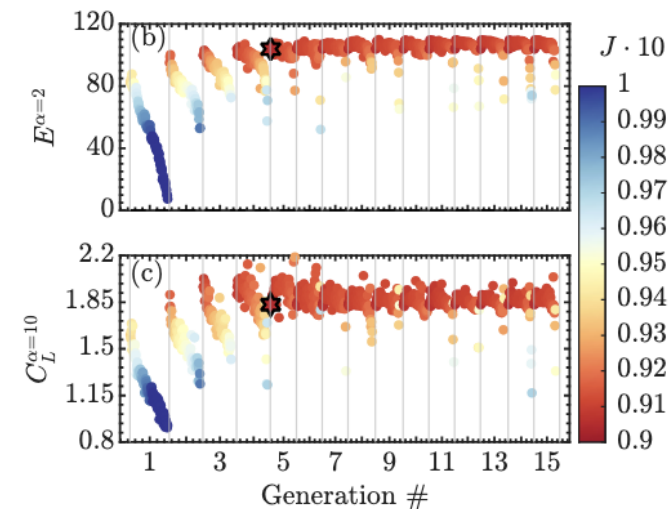
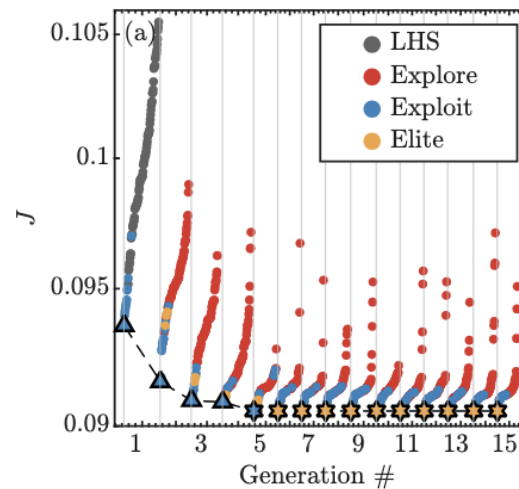
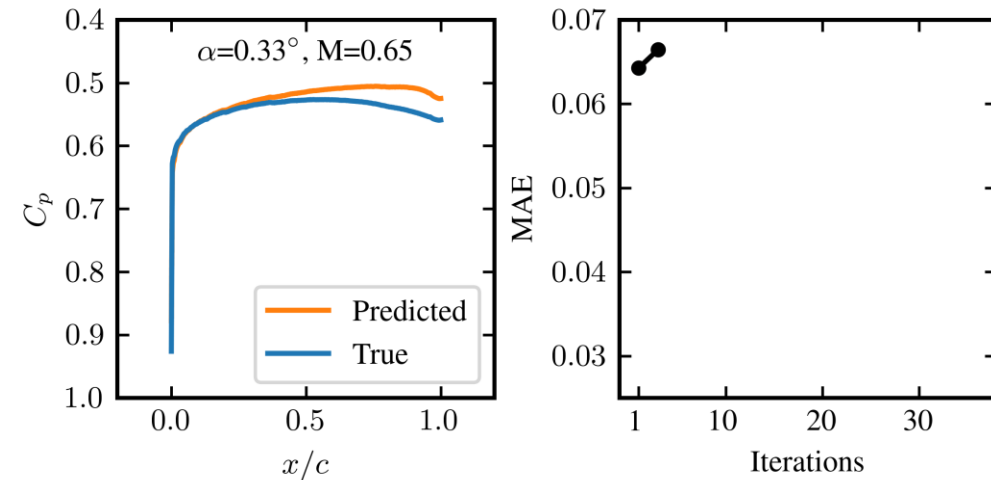
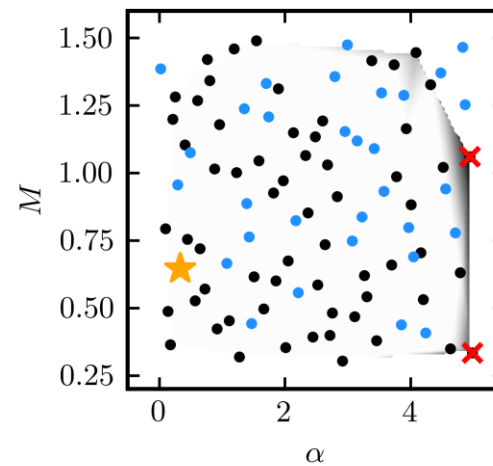
1. Adaptive Sampling

- Intelligently select points to build a database
- Conformal prediction
- Design of Experiments

2. Multi-Fidelity Shape optimization

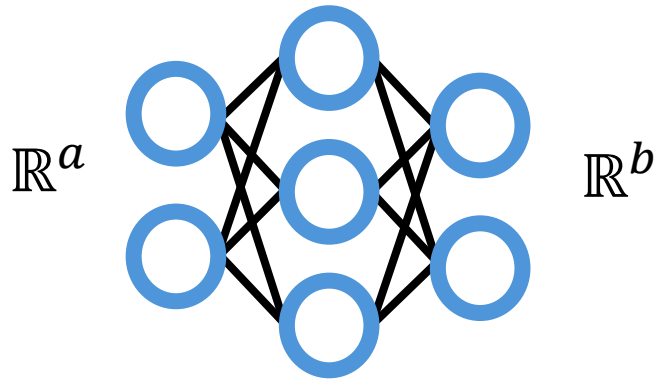
- Embedded on the optimization
- Automatic high-Fidelity triggering

3. Soft-physics

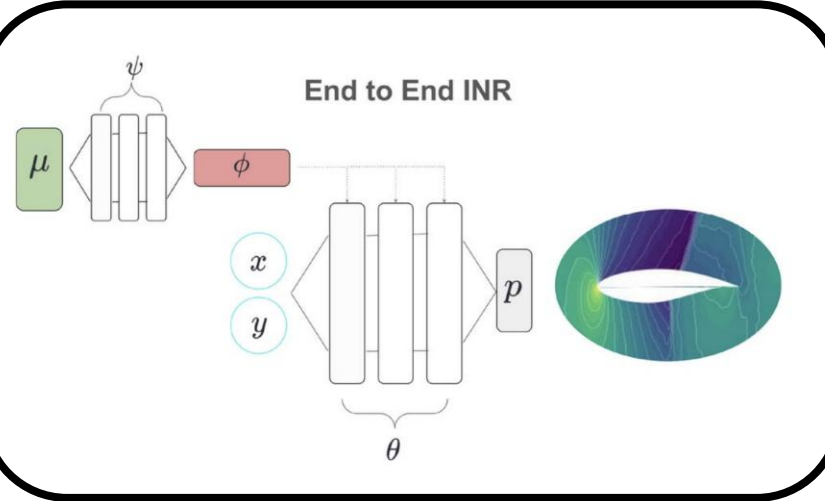


State of the art: Overcomplicating architectures

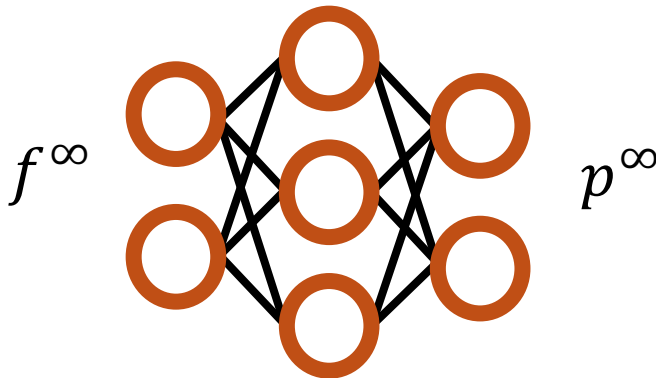
Neural Network



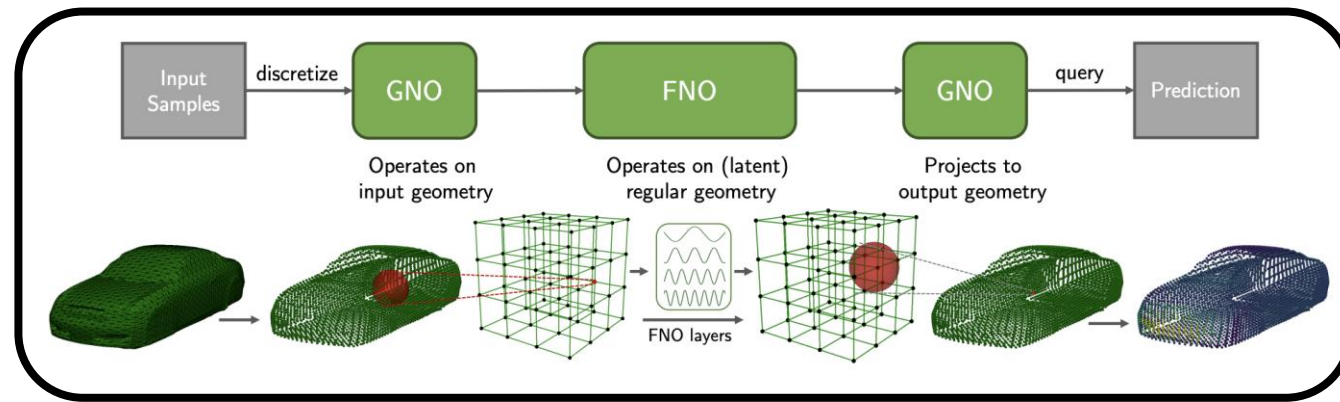
Catalani et. al. 2024, Scientific Reports



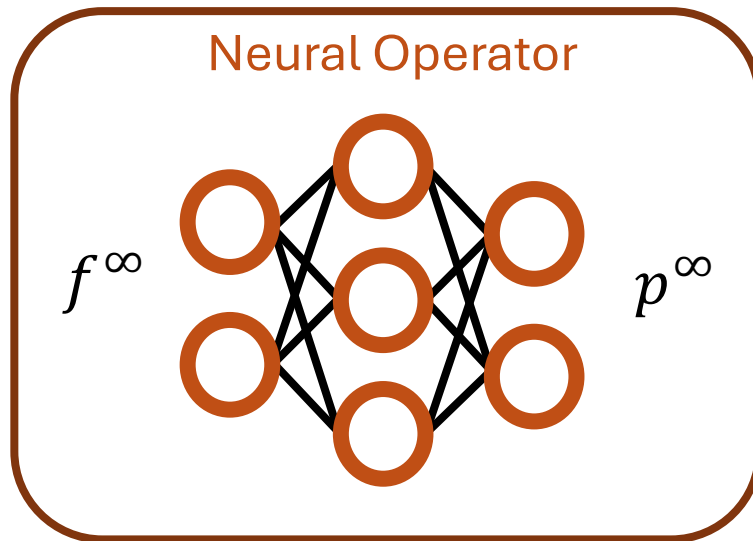
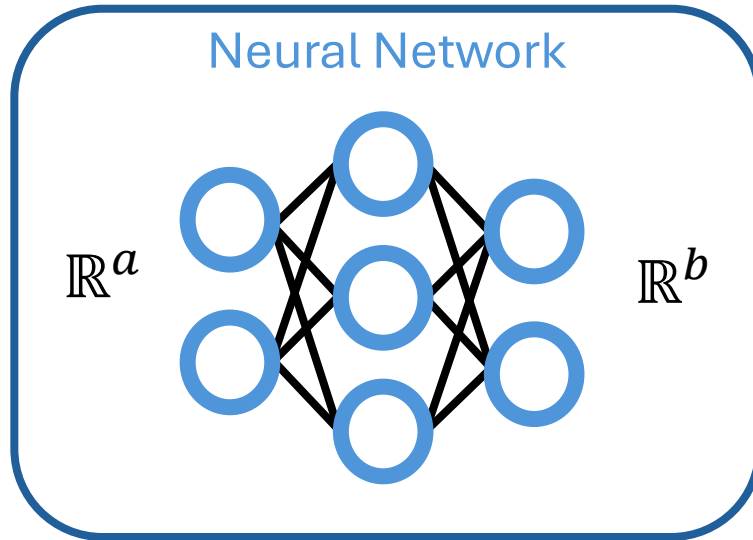
Neural Operator



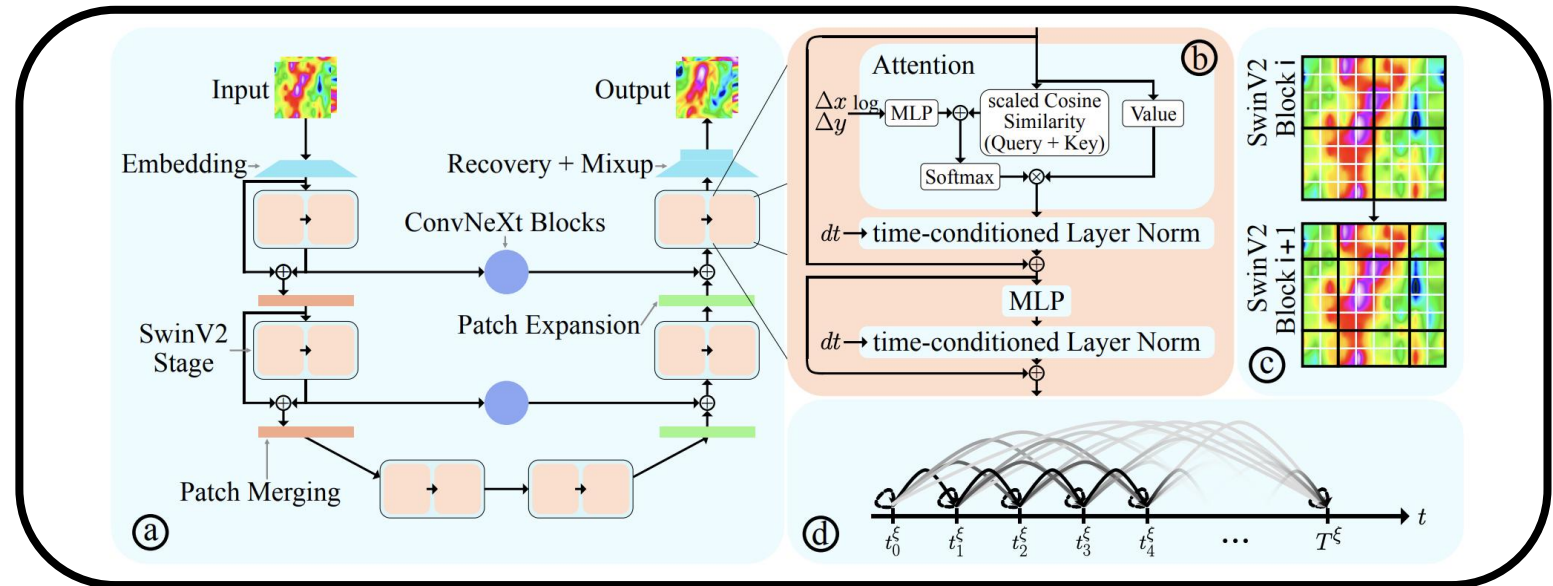
Li et. al. 2023, Arxiv



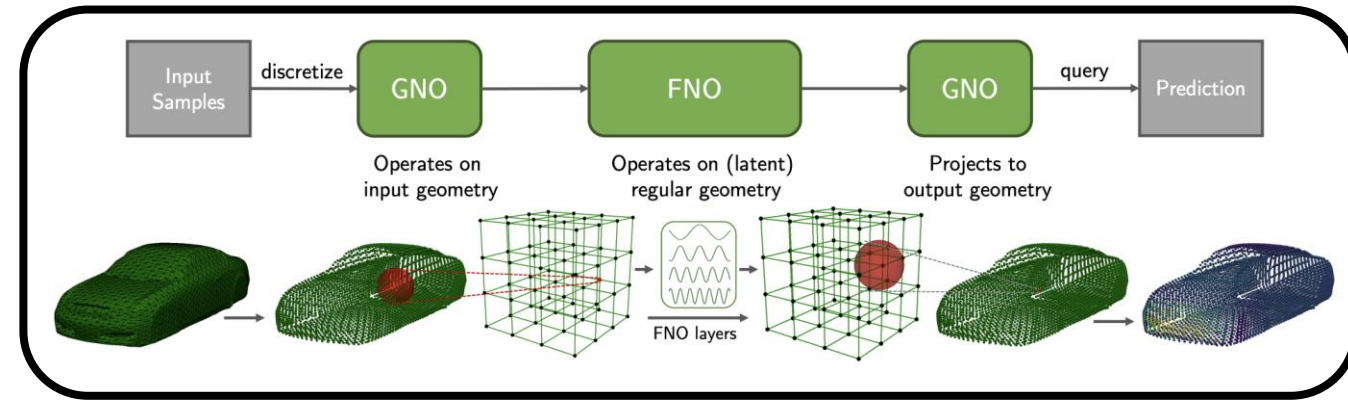
State of the art: Overcomplicating architectures



Herde et. al. 2024, *Advances in Neural Information Processing Systems*

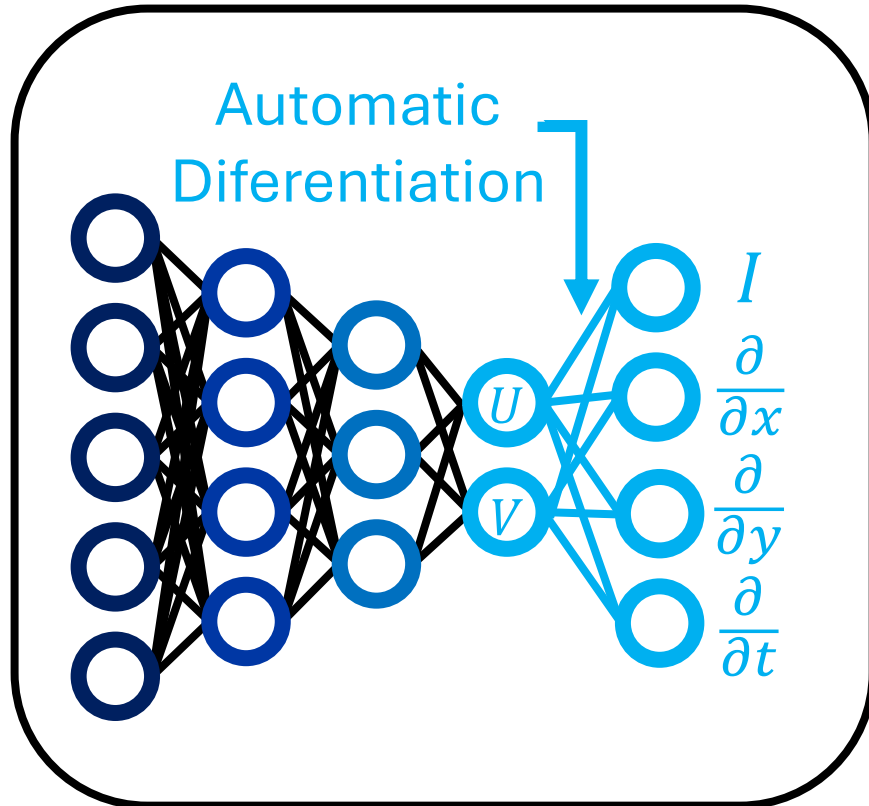


Li et. al. 2023, *Arxiv*

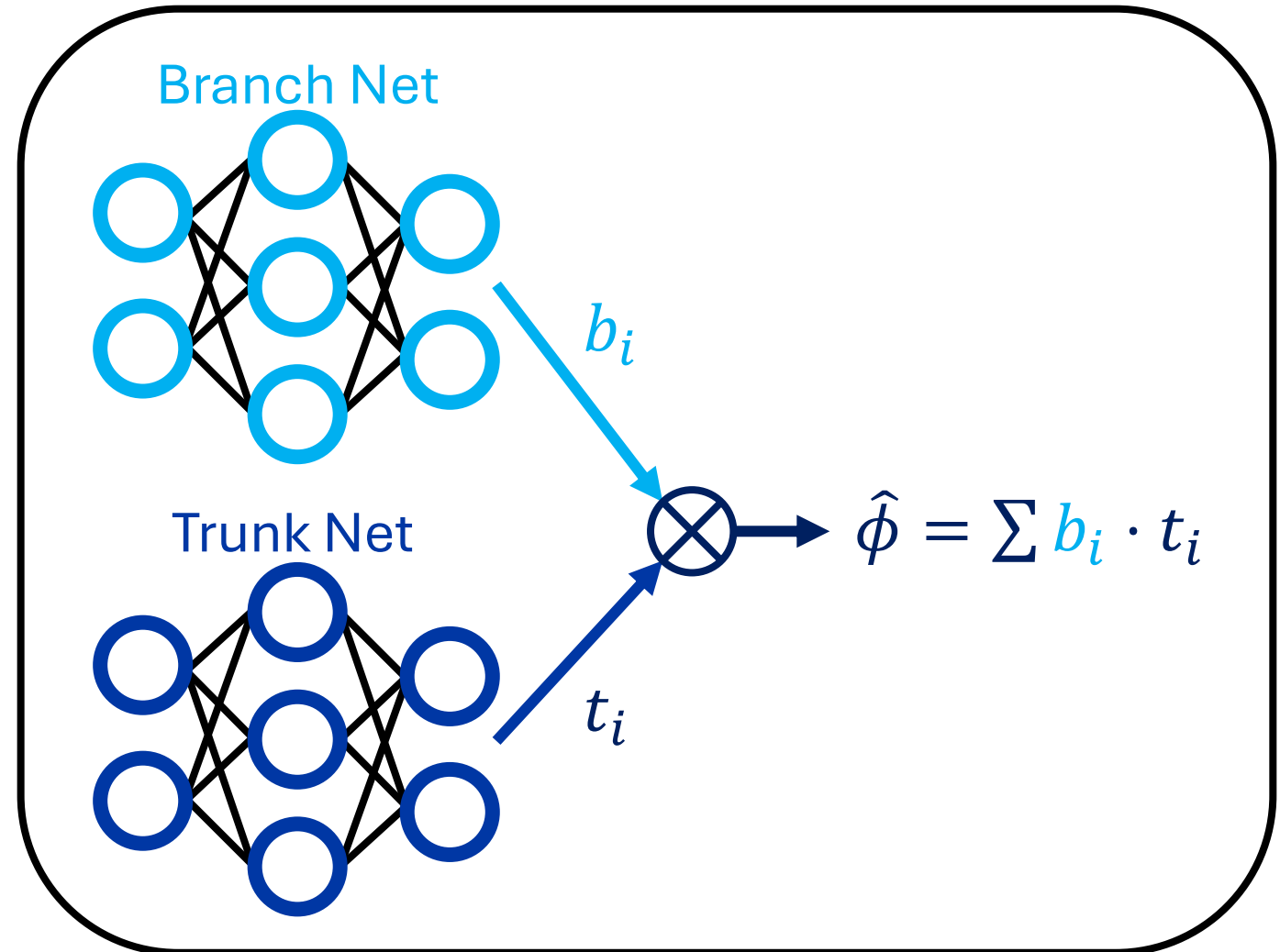


My approach: Efficient use of readily available information

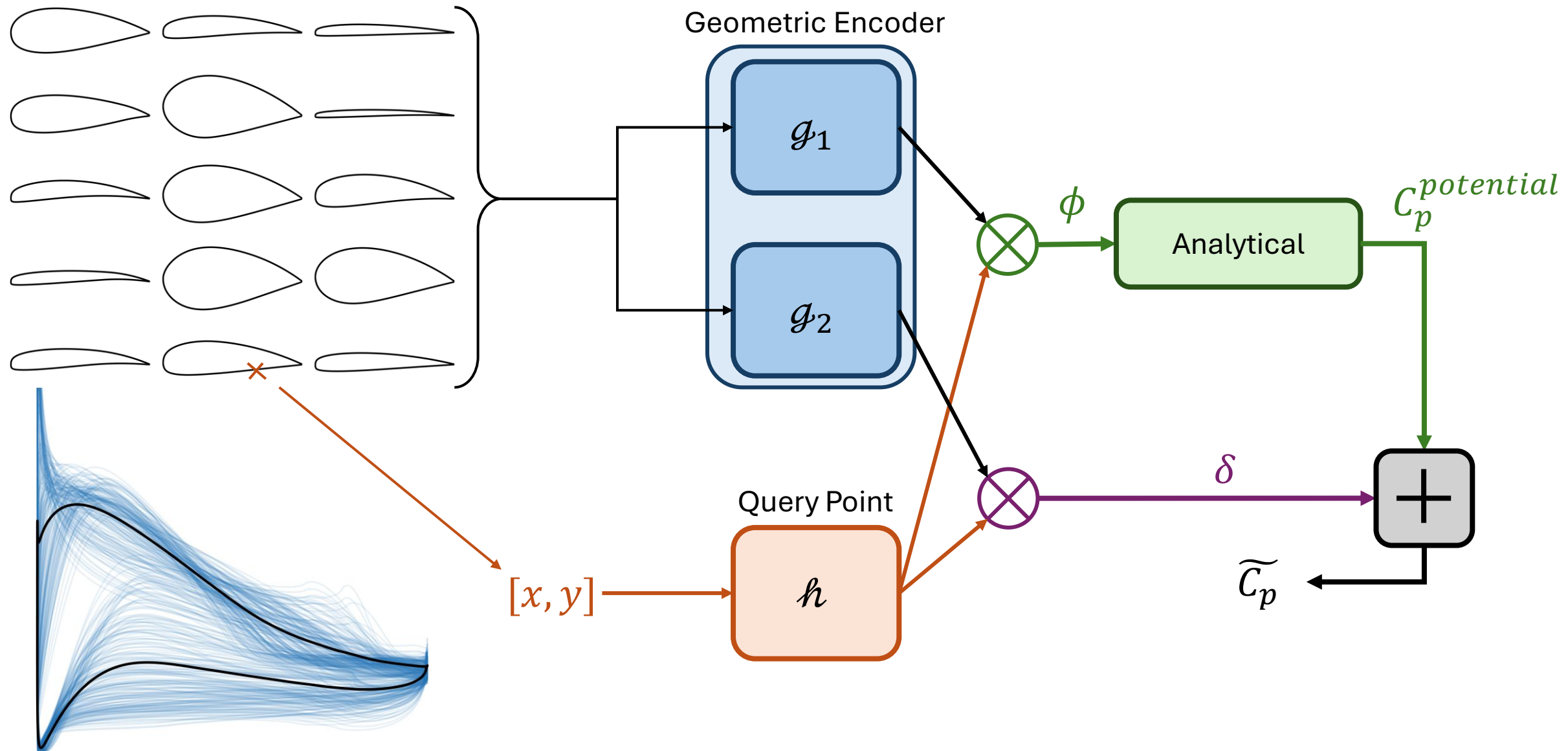
PINNs



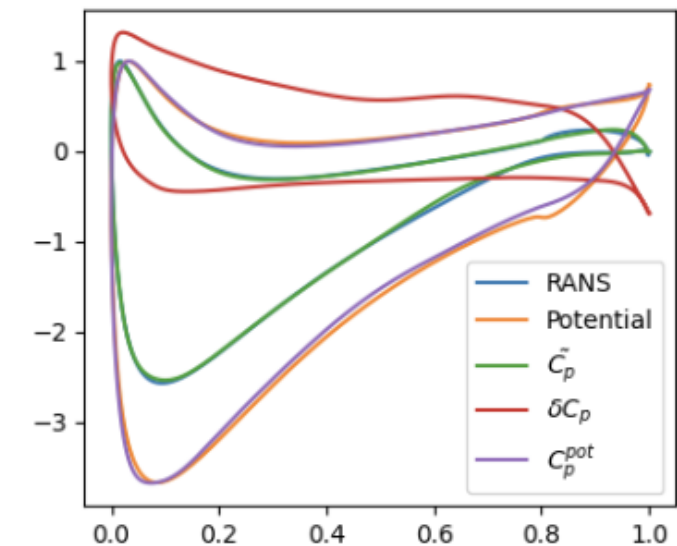
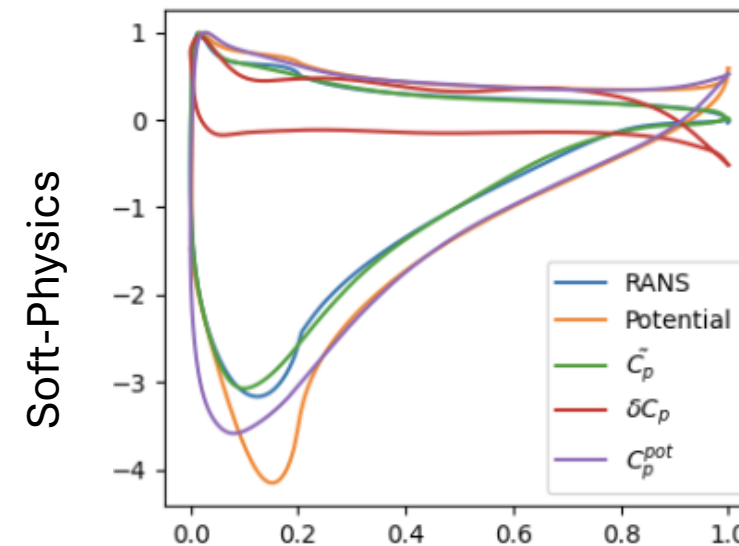
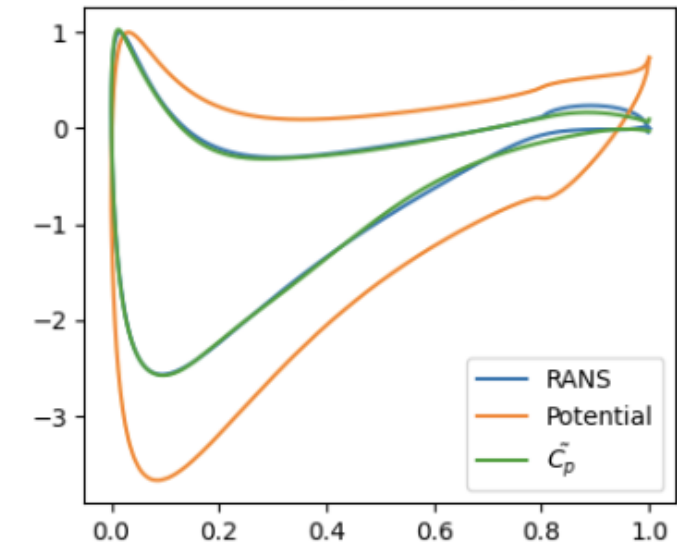
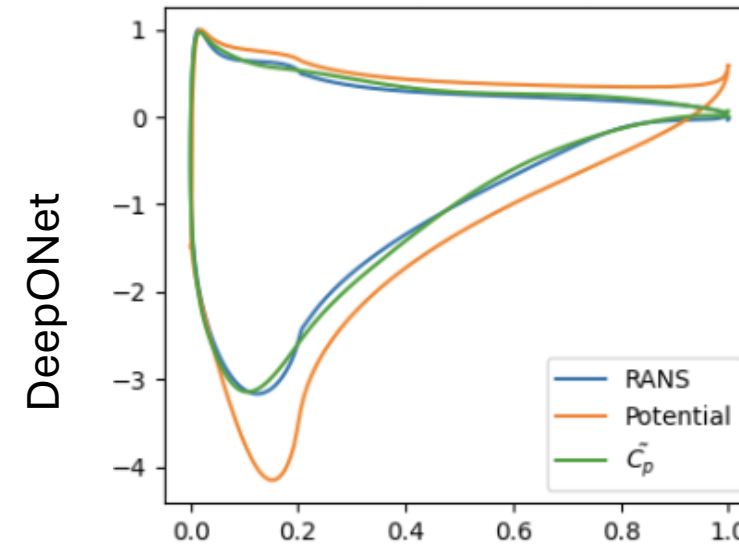
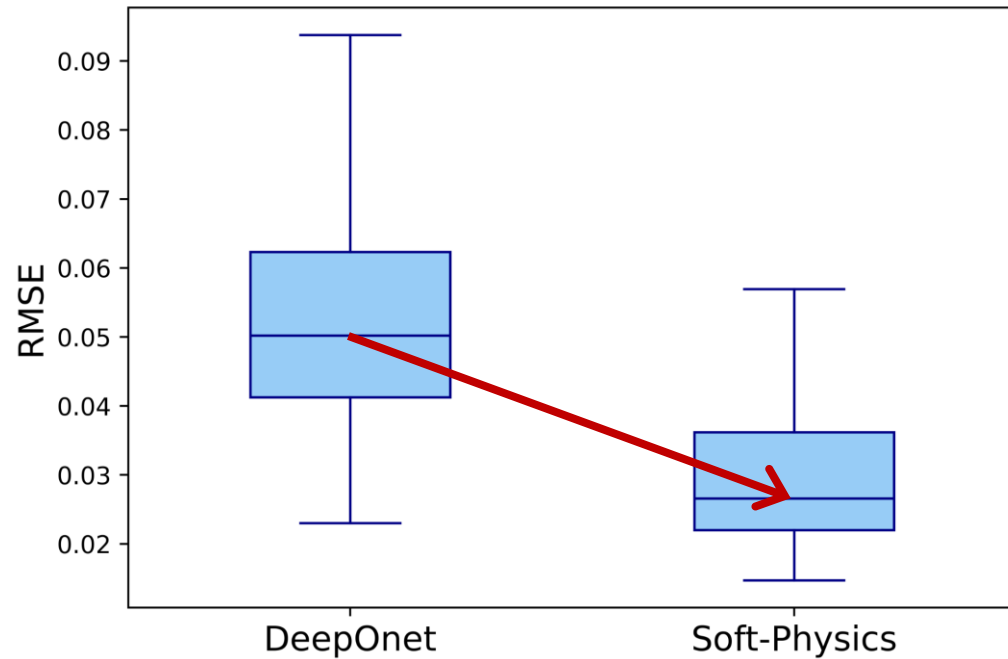
DeepONet



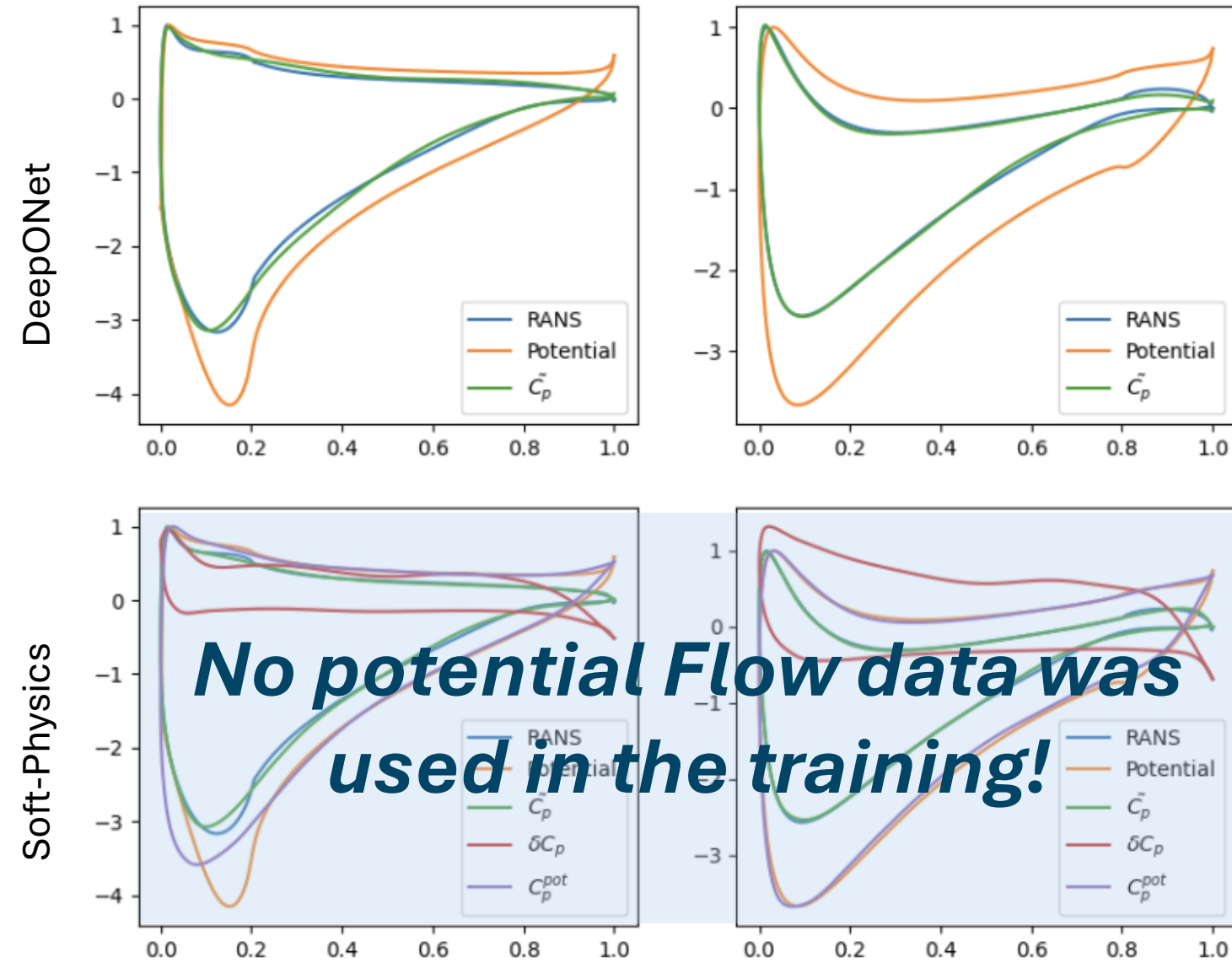
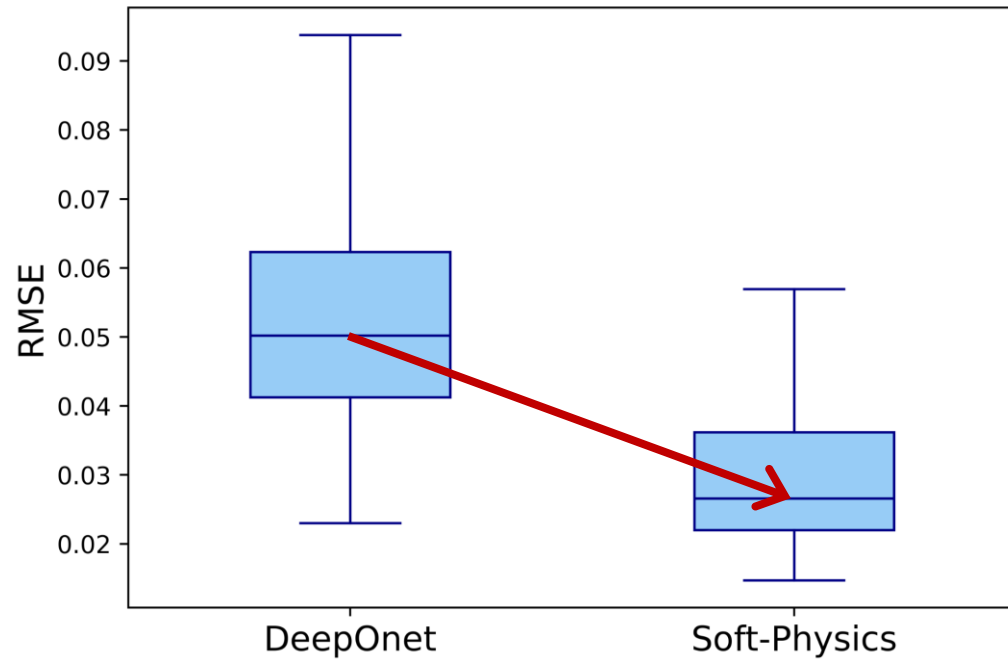
My approach: Efficient use of readily available information → Soft-Physics



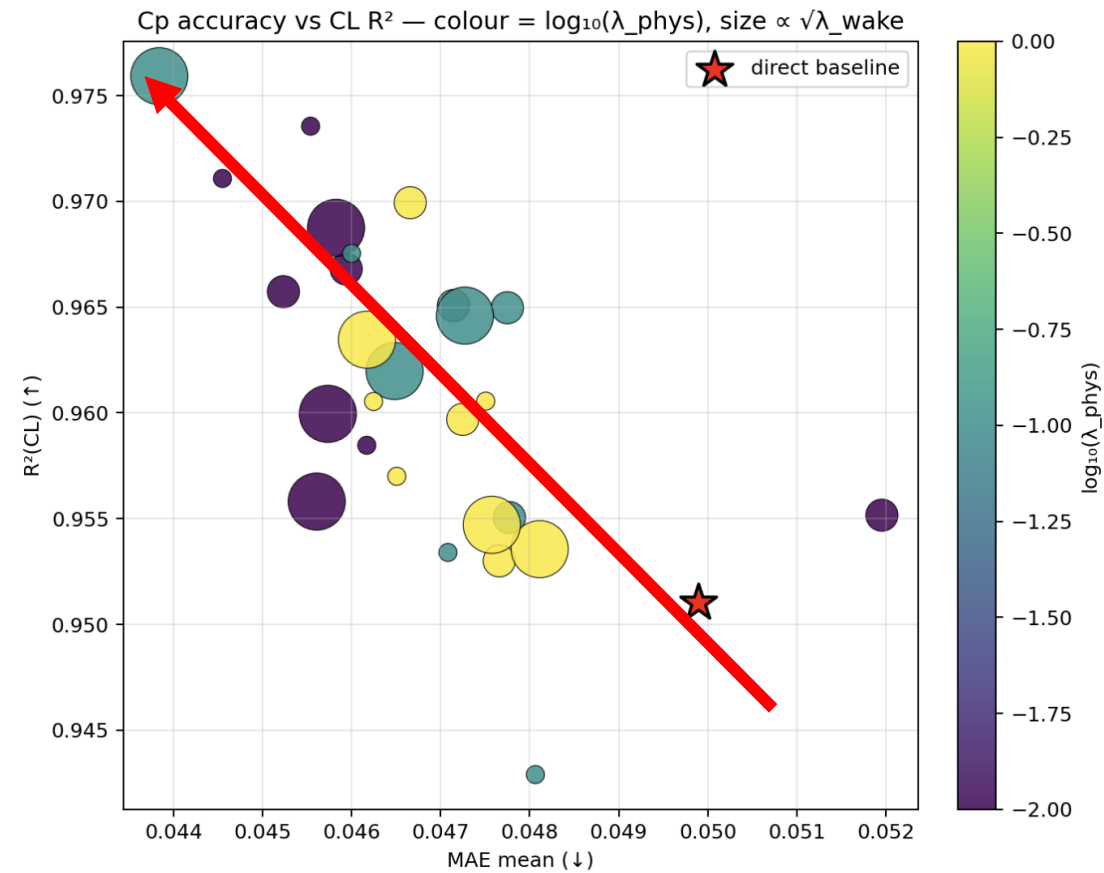
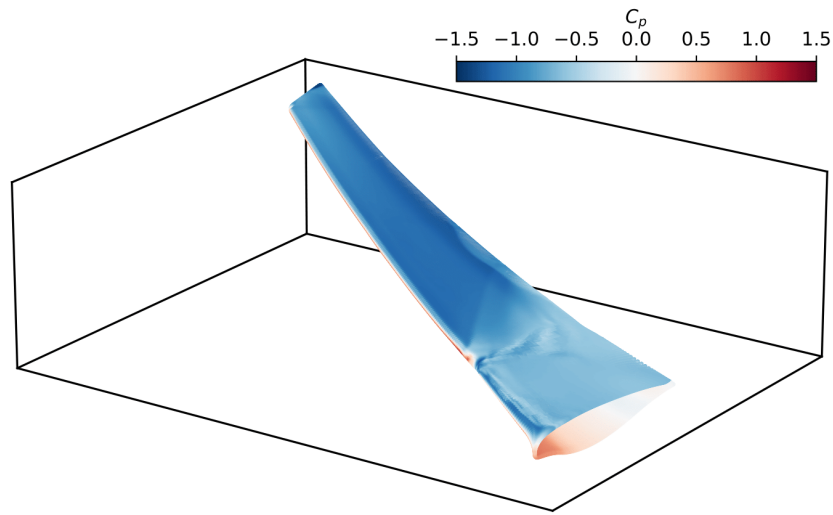
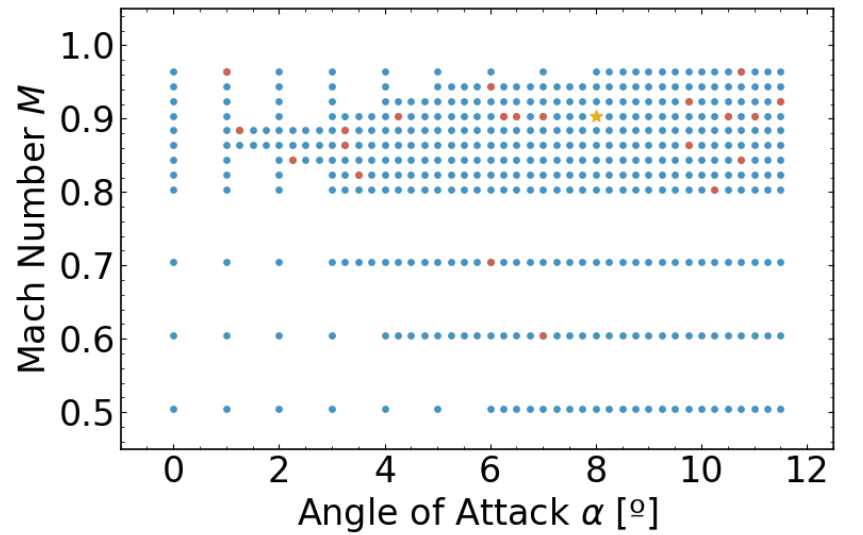
Soft-Physics: 2D Surface Cp predictions



Soft-Physics: 2D Surface Cp predictions



Soft-Physics: 3D Surface C_p predictions on transonic database





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Research paper

Fast and robust parametric and functional learning with Hybrid Genetic Optimisation (HyGO)

Isaac Robledo ^a✉, Yiqing Li ^b✉, Guy Y. Cornejo Maceda ^a✉, Rodrigo Castellanos ^a✉ [Show more](#) ▼

[View PDF](#) [Download full issue](#) [Cite](#) [Add to Mendeley](#) [Share](#) | 10.1016/j.advengsoft.2026.104139 ➤

for Multi-Condition Airfoil Shape Optimization

Isaac Robledo, Alberto Vilariño, Arnau Miró, Oriol Lehmkuhl, Carlos Sanmiguel Vila, Rodrigo Castellanos

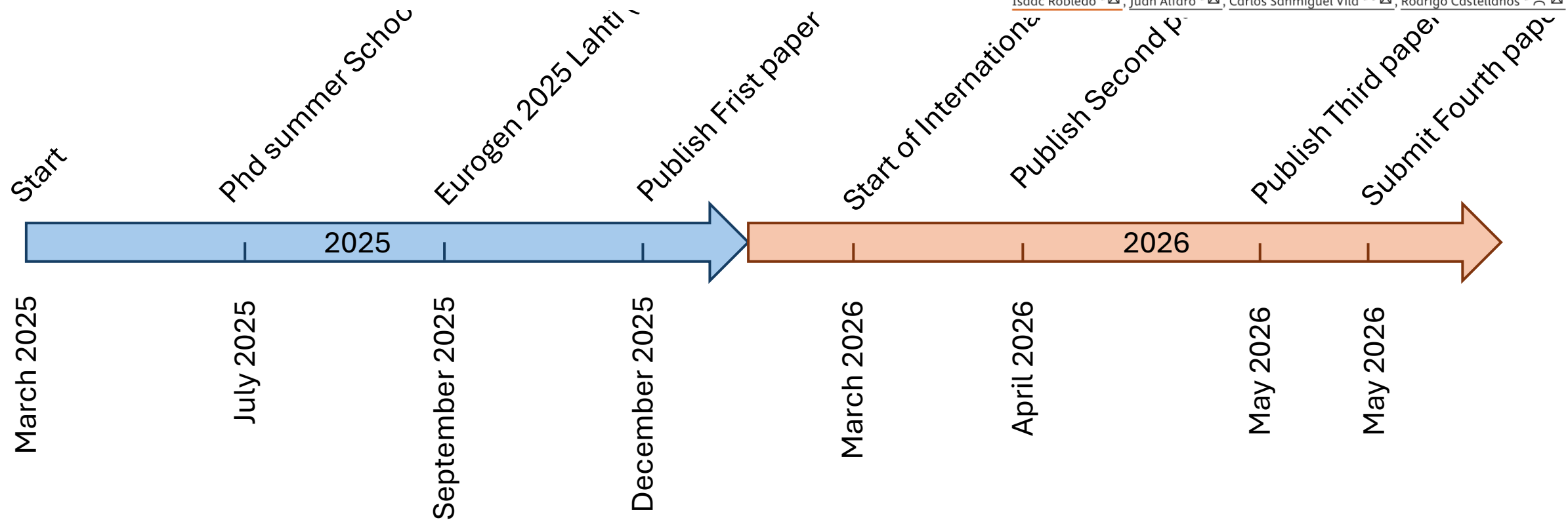


Experimental Thermal and Fluid Science

Volume 169, December 2025, 111526

steady convective heat transfer of an
singing sweeping jet: A discussion on the
effect of spatiotemporal filtering

Isaac Robledo ^a✉, Juan Alfaro ^a✉, Carlos Sanmiguel Vila ^{a b}✉, Rodrigo Castellanos ^a✉



Questions?

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