Hybrid analysis and modeling for next generation of digital twins

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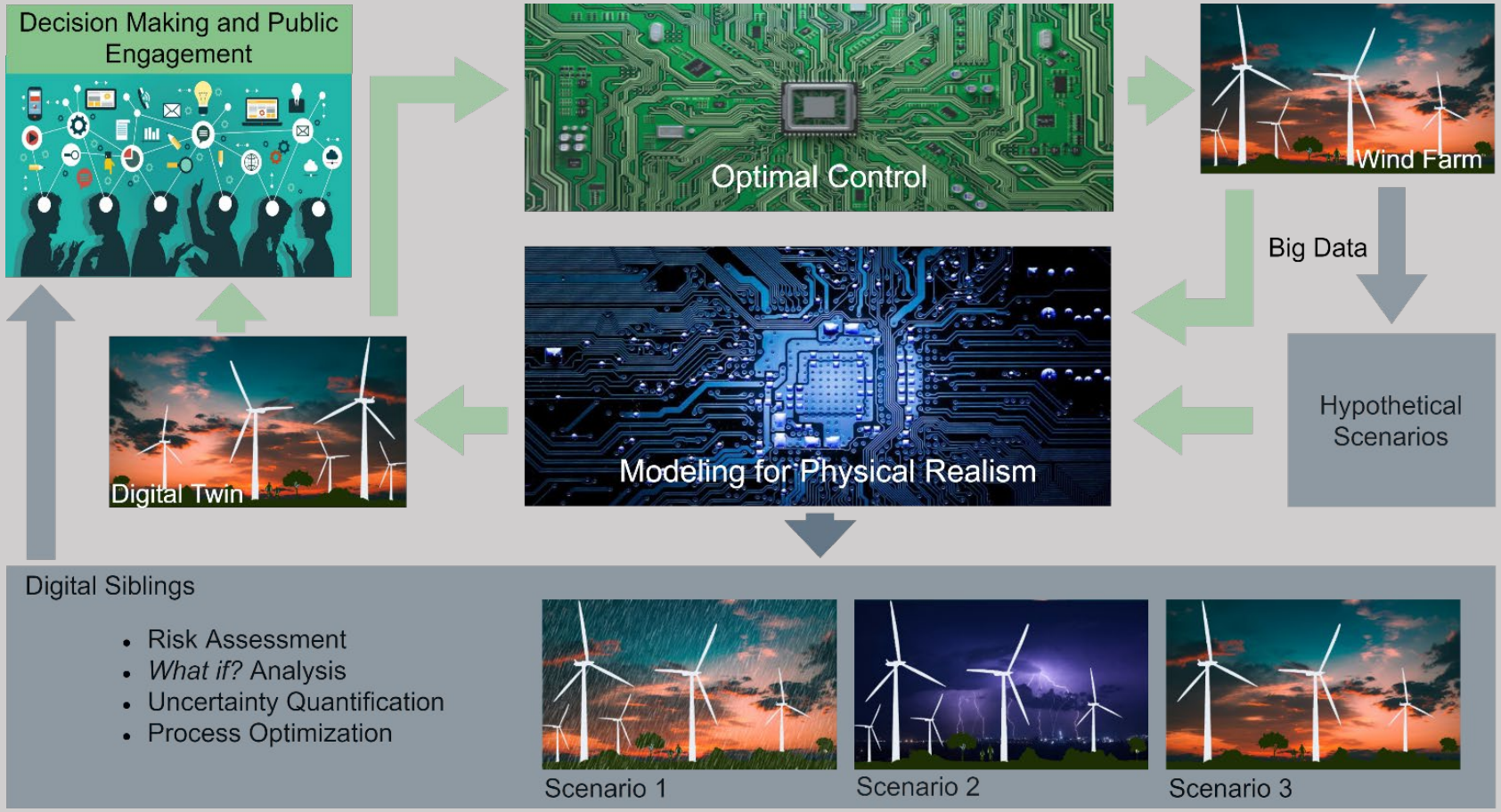
Digital Twin



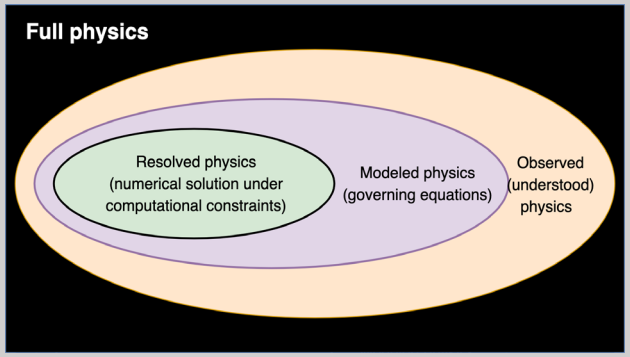
Requires models which are

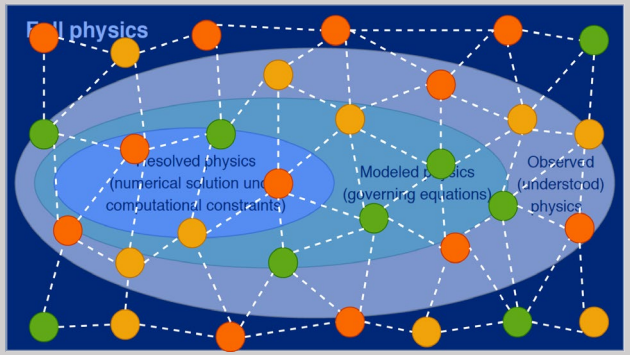
- Computationally Efficient
- Trustoworthy
- Accurate and certain
- Generalizable

Seamless integration

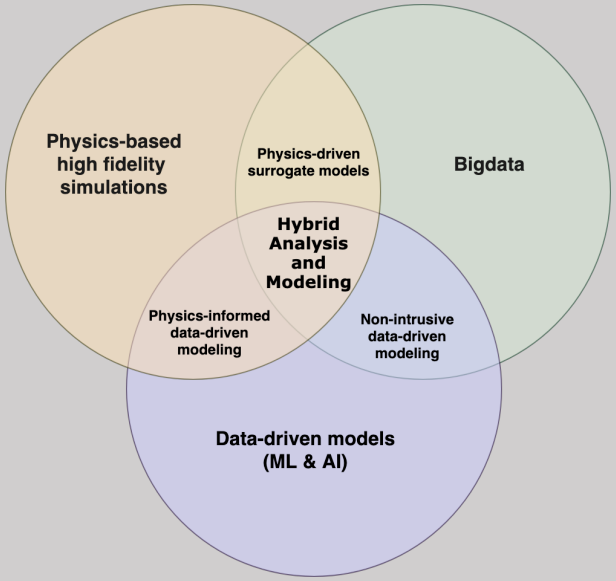
- Multiphysics
- Multiscale
- Multifidelity

State of the art



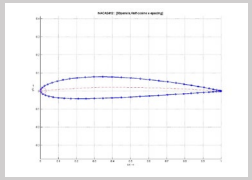


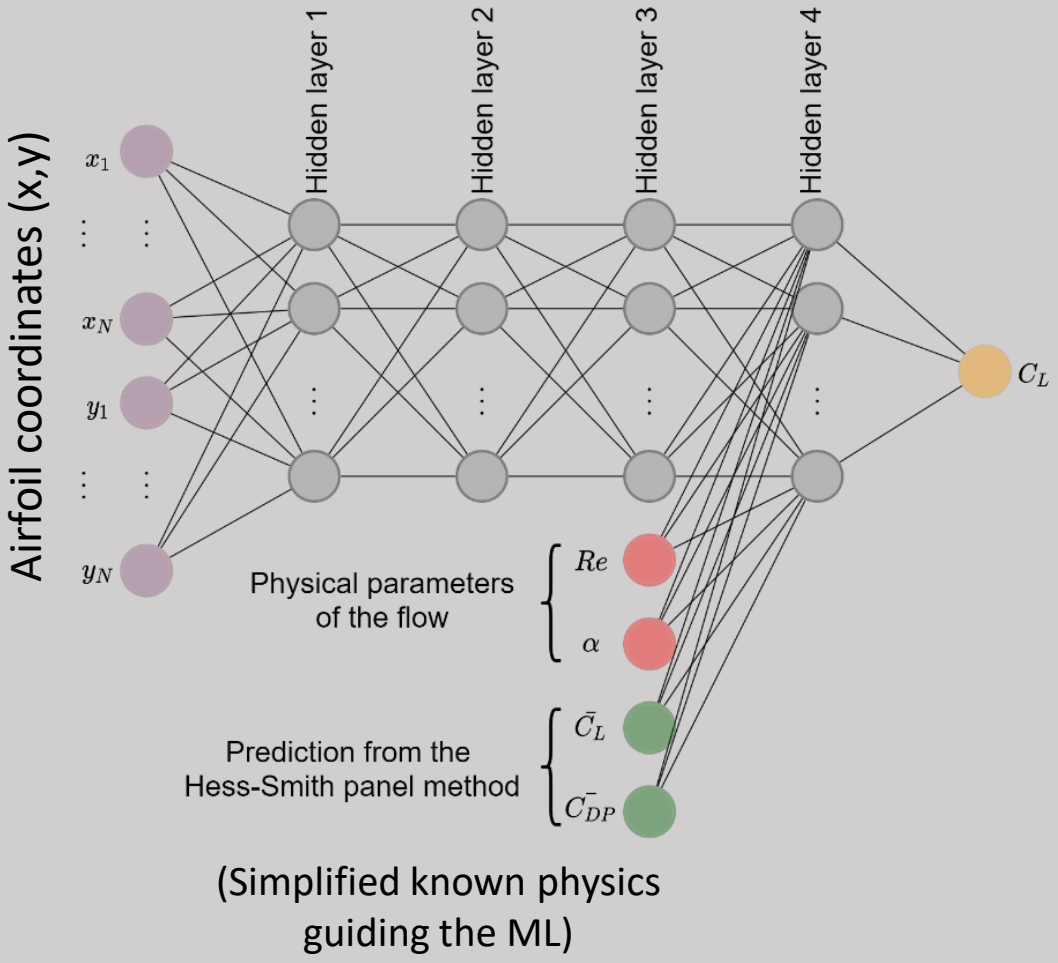
Physics based modeling	Data driven modeling
Solid foundation	Black box and discard even known physics
Difficult to assimilate very long-term historical data into the computational models	Takes into account long term historical data and experiences
Numerical instability	Stable once trained
Uncertainties can be bounded and estimated	No such guarantee
Less biased	Biased
Good generalization	Poor generalization on unseen problems



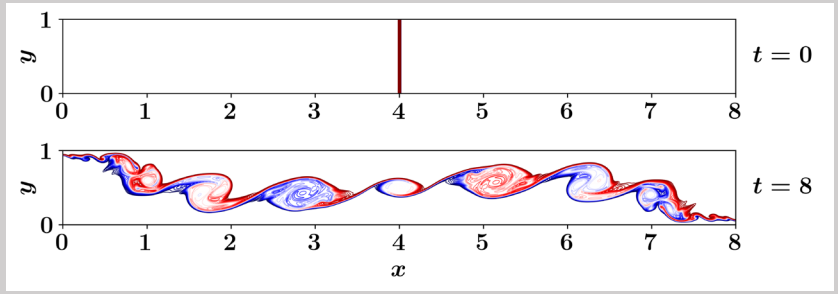
HAM is a modeling approach that combines the ***interpretability, robust foundation*** *and* ***understanding*** *of a* ***physics-based approach*** *with the* ***accuracy, efficiency,*** *and* ***automatic pattern-identification*** *capabilities of advanced* ***data-driven*** *machine learning and artificial intelligence algorithms to produce less uncertain results.*

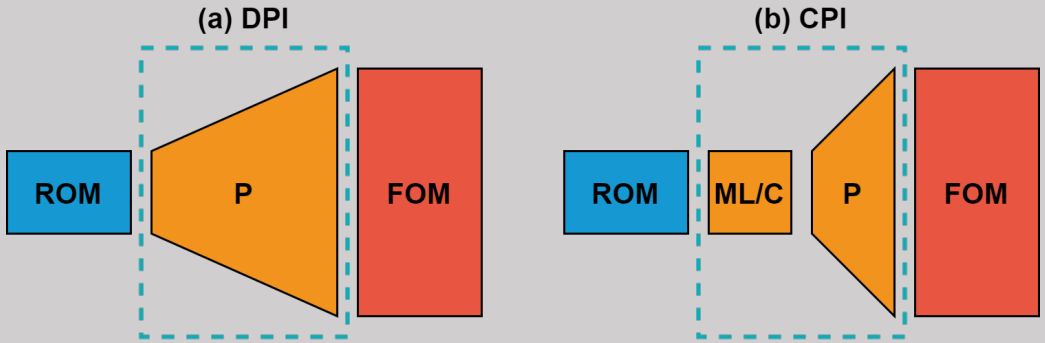
HAM: 2 Proposed approaches

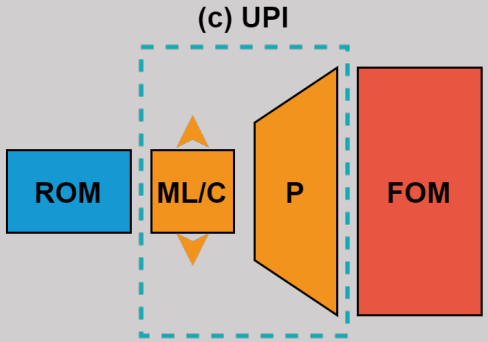




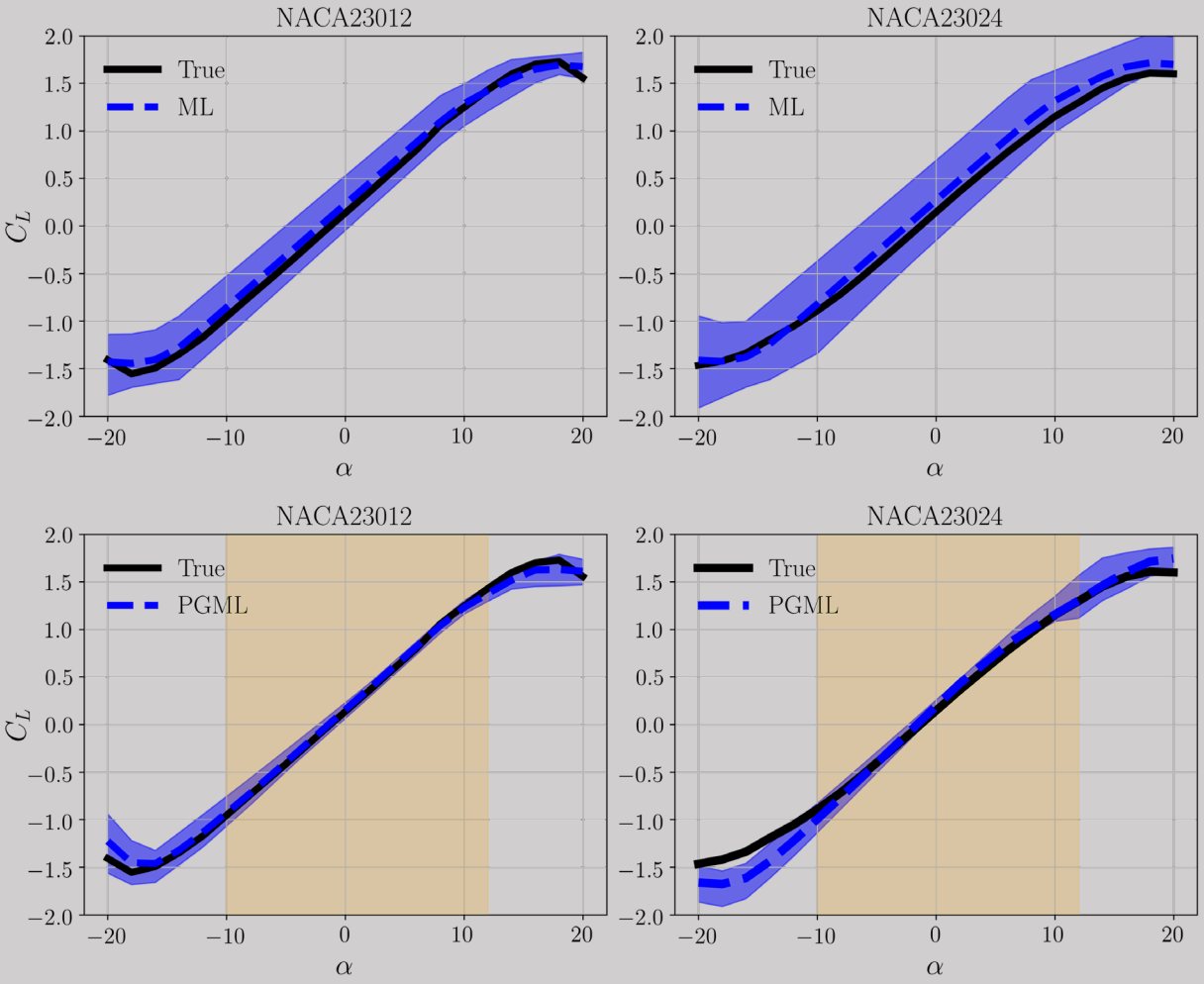
(Simplified known physics guiding the ML)

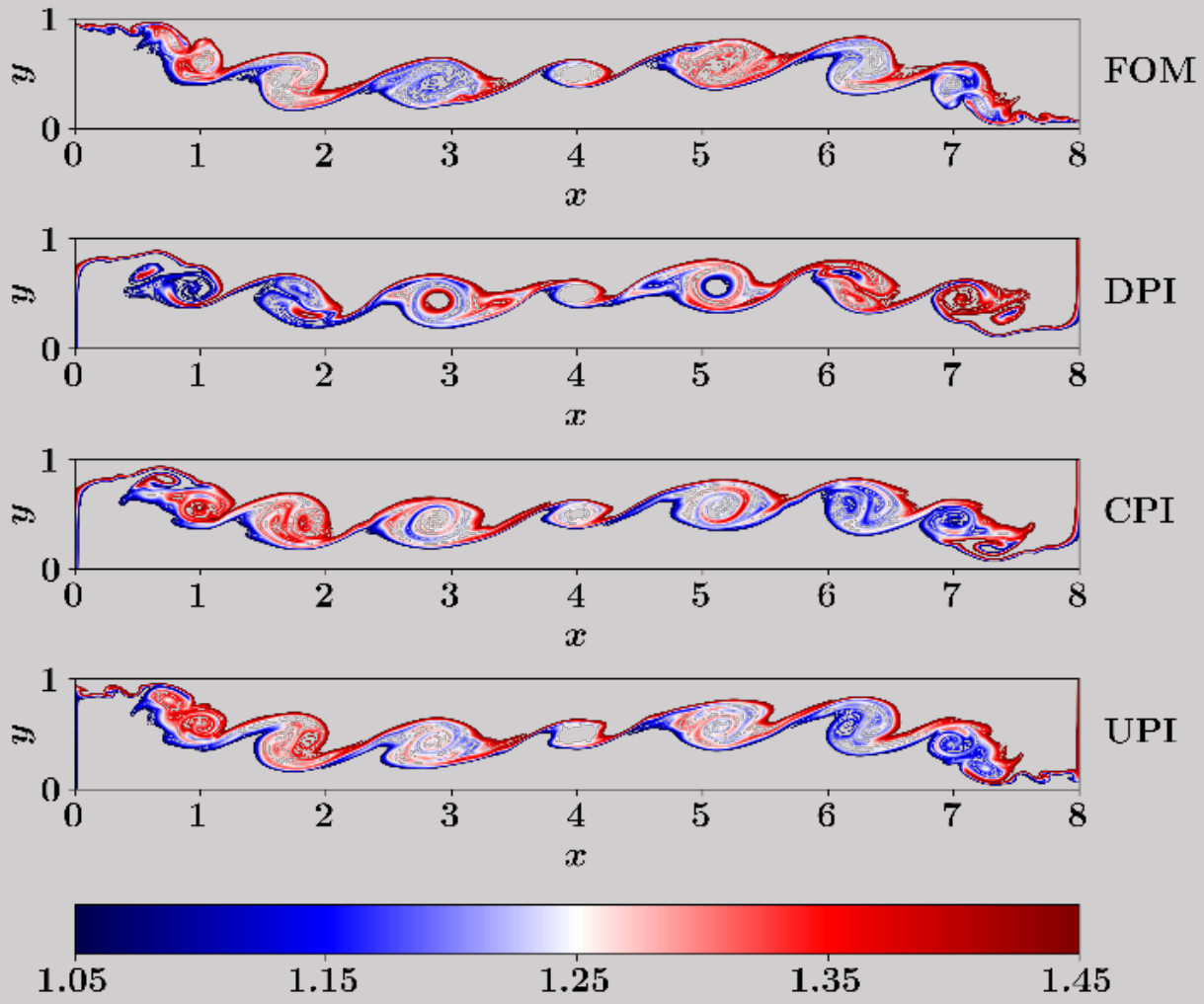






Results


NACA23012
NACA23024
True
ML
PGML
C_L
α


FOM
DPI
CPI
UPI
y
x
1.05
1.15
1.25
1.35
1.45

Conclusion

- A novel Deep Learning architecture which enables injection of partially known physics leading to a more certain model 75% reduction in uncertainty for the smaller angle of attacks (i.e., -10^{o} to 12^{o}).

- A novel Interface Learning technique which elegantly couples multi-fidelity models leading to approximately 10x computational speed over the full order model.