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Physics-informed neural networks: The tug-of-war between knowledge and noise

Physics-informed neural networks (PINNs) have emerged as a coherent framework to build predictive models that combine statistical patterns with domain knowledge. The underlying notion is to enrich the optimization loss function with known equations to constrain the space of possible model solutions. Successful applications cover a variety of areas, including physics, astronomy and bioinformatics. This study investigates the effect of two components within PINNs. First, knowledge-encapsulating physical laws, purposely injected into the learning mechanism and independent of the training data, are used to constrain the model bias and improve generalization performance. Secondly, noisy data has a substantial impact on the search for accurate models when dealing with limited sensors and systematic errors, which can lead to poor generalizations. We use the Bateman–Burgers equation, commonly used in fluid mechanics and nonlinear acoustics, to understand the tug-of-war between knowledge injection and noise perturbation when building models using PINNs.

Significance

Current state-of-the-art developments in physics-informed neural networks fail to provide a clear understanding of the effect that noise and knowledge exert on the final model's generalization performance. As understanding the role of knowledge as a regularization factor, to narrow the space of possible models, is critical to a number of applications in physics, our study shines a light on these topics and provides new insights. The medium-term direction of this investigation focuses on galaxy evolution in theoretical astrophysics, as well as comparisons to observational telescope data in the same domain, to establish an investigative tool for not yet ascertained variable relationships.

References

Experiment context, if any

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