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Topological Stability of Neural Operators: A Nonlinear Functional–Geometric Theory for Controlling Infinite-Dimensional Learning Systems

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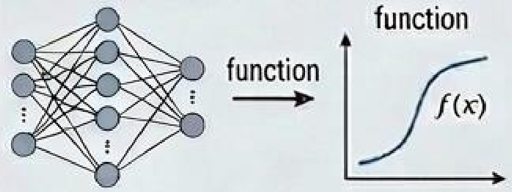
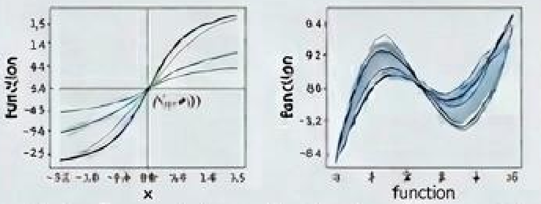
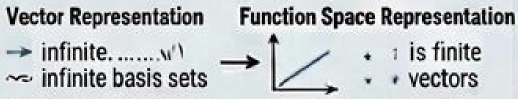
INTRODUCTION & AIM



Neural Network → Neural Operator



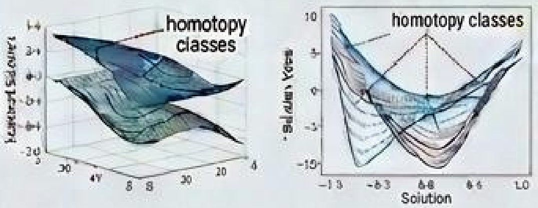


- Developing a rigorous unified framework for stability, controllability, and generalization in function spaces.

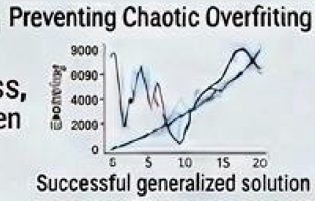
RESULTS & DISCUSSION

TOPOLOGICAL GENERALIZATION & STABILITY

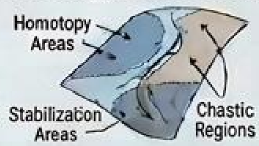
Learned Solution Manifolds



- Generalization governed by homotopy class, navigated unseen test regimes



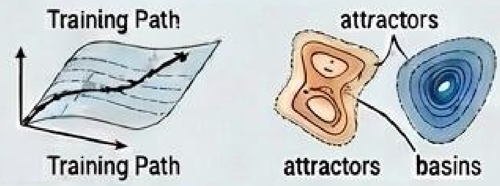
- Architectural choices enforce global geometric constraints

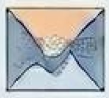


- Degree theory used to quantify global geometric structure and avoid underdetermined learning instabilities.

METHOD

Learning as a Topological Flow

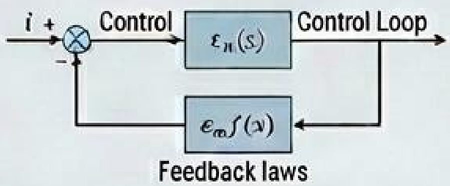




Topological Loss Function Design: Integrating degree constraints for robust optimization.

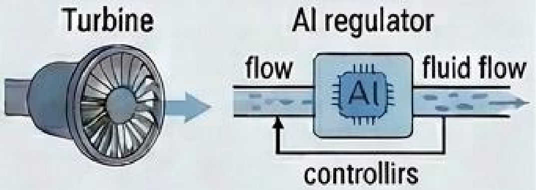
$$\mathcal{T}_{\text{topological}} + f(x) = \frac{1}{2m}\sum_{i=1}^{n}\left((\text{topological loss})\right)^2$$

Control Theory Application



- Training algorithms as feedback control laws (e.g. the usalient woriossional, ...Route to stability-certified *and robustiy controllable* infinite-dimensional state space.

CONCLUSION



- Verified framework for designing AI controllers with provable stability guarantees for physical systems.

FUTURE WORK

- Extension to higher-order manifolds
- Applications to quantum many-body problems
- Integration with causal inference for robust, safe AI control of unmodeled systems.