An Exploratory Platform for Physics-Informed Damage Identification in Beams

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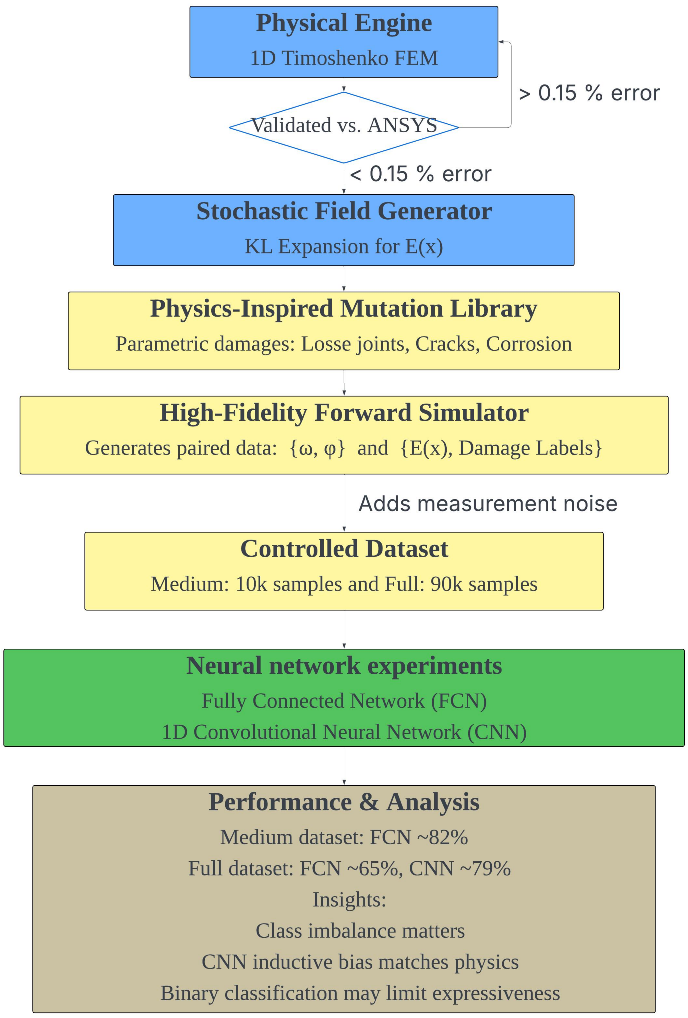
CORE QUESTION :

Can we identify localized damage in a beam using only its low-order vibration modes?

This project builds a transparent, physics-grounded computational platform to investigate this inverse problem and critically evaluate data-driven approaches.

METHODOLOGY FRAMEWORK:



KEY FINDINGS & CENTRAL INSIGHT:

I trained FCN and 1D-CNN as baseline probes on datasets of varying sizes.

Observation:

1. **Medium dataset** (10k samples): FCN accuracy ~82%
2. **Full dataset** (90k samples): FCN accuracy drops to ~65%, while CNN accuracy rises to ~79%

Interpretation:

1. Severe class imbalance allows FCN to **overfit** the dominant "healthy" class.
2. CNN inductive bias better matches **the localized nature of damage**.
3. **Core limitation**: Even the better model is constrained, suggesting a fundamental mismatch between binary classification and the continuous, uncertain nature of stiffness degradation.

These observations suggest that the limitation lies not merely in model capacity, but in the formulation of the inverse problem itself.

POSSIBLE DIRECTIONS IN THE FUTURE:

1. **Problem Reformulation**: From damage classification to continuous stiffness field regression
2. **Embracing Uncertainty**: Bayesian inference to quantify prediction confidence

CONCLUSION:

I think this exploratory work naturally leads to questions at the heart of modern Structural Health Monitoring research: **how to formulate well-posed inverse problems under uncertainty, and how to integrate physical models with data-driven learning in a principled way**. I am eager to explore these methodological challenges in depth.

PROJECT NOTES:

This project is open-source. Full code, documentation, and analysis are available. I welcome and look forward to any questions, discussions, or potential collaboration! Please feel free to open an issue on GitHub or reach out via email.

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