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DOMAIN AGNOSTIC NEURAL OPERATORS FOR DATA-DRIVEN FRACTURE MODELING

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ABSTRACT

Over the past several decades, physics-based governing equations have been the cornerstone for modeling fracture problems. Traditional numerical methods have been employed to solve these equations and various approaches have been proposed to capture the evolving frature interfaces. However, their accuracy and computational feasibility can be compromised when dealing with unknown governing laws or complex interface geometries, such as in crack propagation and heterogeneous material design problems.

In this talk, we develop to use data-driven modeling approaches to learn the hidden physics, capture irregular geometries, and provide accelerated predictions. In particular, we introduce domain agnostic Fourier neural operator (DAFNO) [1], which learns the surrogate mapping between loading conditions and the corresponding physical responses with irregular geometries and evolving domains. The key idea is to incorporate a smoothed characteristic function in the integral layer architecture of neural operators, and leverage FFT to achieve rapid computations for evaluating these integrals, in such a way that the geometric information is explicitly encoded in the architecture. Once trained, DAFNO can provide efficient predictions for physical problems under unseen loading scenarios and evolving domain geometries, which makes it especially suitable to handle the complex interfacial problems in fracture mechanics. To illustrate the applicability of DAFNO in fracture problems, we show two examples. Firstly, we consider a brittle material crack propagation problem which features complex domains with topology changes. Then, in the second example we further consider the corrosion induced cracking in reinforced concrete, which is a multiphysics system involving the interactions between diffusion, chemical reaction, mechanical strain, and crack fields. Last but not least, we show that DAFNO can act as an efficient surrogate for the inverse microstructure design. These examples highlight the features of DAFNOs in its generalizability, flexibility, and efficiency.

REFERENCES

[1] N. Liu, S. Jafarzadeh, Y. Yu, Domain agnostic fourier neural operators, arXiv preprint arXiv:2305.00478.