VANDERBILT UNIVERSITY School of Engineering

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

Seminar

Friday,

April 21, 2023

12:10 pm – 1:10 pm

FGH 211

"APPLICATIONS OF GRAPH NEURAL NETWORKS FOR EMULATING & ACCLERATING FRACTURE MECHANICS PROBLEMS"

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ABSTRACT

Simulating fracture mechanics problems requires the use of high-fidelity fracture models where computational costs scale up with problem complexity. A possible solution to circumvent these challenges involves reduced-order modeling techniques, such as Machine Learning (ML). In this work, we use Graph Neural Networks (GNNs) to emulate fracture mechanics problems. GNNs work by integrating supervised ML with graph theory. In this work, we develop two GNN-based frameworks, one for accelerating XFEM-based fracture simulations and another for phase-field fracture simulations.

The first GNN framework, called Microcrack-GNN, emulates fracture and stress evolution in brittle materials due to multiple microcracks' interaction. Microcrack-GNN is trained on the dataset generated by the XFEM-based fracture simulator. The framework predicts mode-I and mode-II stress intensity factors, identifies which microcrack will propagate, and then predicts the position of the crack tip at the next time step. Next, we use the transfer learning approach to extend this framework to work for arbitrary domains and loads.

The second GNN framework, called ADAM-GNN, uses mesh-based GNNs where the adaptive mesh represents the graph. We train the framework on phase field fracture simulations with an adaptive mesh. The GNN framework predicts meaningful variables such as x-displacement, y-displacements, and evolving the crack field. We perform predictions on a dynamically adjusting graph, emulating adaptive mesh refinement.

BIOGRAPHY

Vinamra Agrawal is an Assistant Professor in the Department of Aerospace engineering at Auburn University with an adjunct appointment in the Department of Geosciences. He received his bachelor's in mechanical engineering from the Indian Institute of Technology Kanpur in 2011 and his Master's and Ph.D. in Mechanical Engineering from the California Institute of Technology in 2012 and 2016, respectively. His primary research interests are in high strain rate mechanics, multiscale methods, and machine learning assisted mechanics. His work is supported by the National Science Foundation, the Department of Defense, and the Los Alamos National Lab.