Bhavesh Shrimali

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SUMMARY

- 7+ years of extensive experience in developing **nonlinear multiscale finite element (FE) codes** for incompressible Hyperelasticity, Viscoelasticity, Electromagnetism using open source tools (**FEniCS**) and commercial software (**Abaqus UEL/UMAT/UHYPER**)
- Strong background in **Scientific Machine Learning (SciML), Physics-Informed Neural Networks, Neural Operators, Generative AI and Optimization**
- Strong fundamentals of **Finite Element Analysis, Continuum Mechanics, Nonlinear Material Modeling (Hyperelasticity, Viscoelasticity, Electr/Magneto-Elasticity), Fracture, Multiphysics/Multiscale response of Composites**
- Extensive experience in scripting (Python/Julia) for Nonlinear Model Fitting, Automatic Mesh Generation (`Gmsh` Python/Julia API), Regression, Pre/Post Processing of FE results obtained from Commercial Software
- Published 8 papers in peer-reviewed journals and delivered 3 conference talks

EDUCATION

University of Illinois Urbana Champaign (UIUC) *Urbana-Champaign, IL*

Ph.D. in Civil and Environmental Engineering, GPA: 4.00/4.00 *April 2023*

M.S. in Computer Science, GPA: 3.98/4.00 *April 2023*

M.S. in Civil Engineering, GPA: 4.00/4.00 *Aug 2017*

Indian Institute of Technology (IIT) Guwahati *Guwahati, India*

B.Tech in Civil Engineering, GPA: 9.22/10.00 *May 2015*

SKILLS

- Languages: Python, Julia, C++, Fortran
- FE Libraries: FEniCS, Firedrake, scikit-fem, NGSolve, GridAP.jl, Ferrite.jl
- Commercial FE Packages: ABAQUS, COMSOL (pre-processing)
- Miscellaneous: Bash, Git, pybind11, Gmsh, Mathematica
- ML Libraries: PyTorch, scikit-learn, JAX, Flux.jl, NeuralPDE.jl

WORK EXPERIENCE

Lead Scientist, Virtual and Digital R&D, Kimberly-Clark *May 2023 - present*

- Contributed to the development of a **Machine Learning framework** to analyze and determine fit-measurements for KC products, using hierarchical image-segmentation and computer vision models
- Developed a **FE framework to run thermo-viscoelastic** simulations of KC products under a wide range of mechanical and thermal loading conditions
- Prepared and fine-tuned datasets for running ML-based surrogate models for determining absorbency properties of materials specific to KC
- Wrote proposals and presented them to leadership on how to integrate AI and ML to accelerate workflows within the Virtual and Digital R&D team as well as the corporate research organization at large
- Delivered a technical presentation on the research work and findings at KC's internal annual technical conference

RESEARCH EXPERIENCE

Rupture of Viscoelastic Solids — *May 2021 - Apr 2023*

Theoretical Component [**preprint**, **paper**]

- Developed a universal criterion to describe the growth of pre-existing cracks in viscoelastic elastomers undergoing arbitrary quasistatic deformations

Numerical Component [**code**]

- Developed a robust framework to simulate incompressible and *nearly*-incompressible viscoelasticity to deal with crack singularities, large deformations and large dissipation at the crack front
- Implemented the framework in the open source library **FEniCS** using non-conforming Crouzeix-Raviart finite elements (FE) in space and an adaptive high-order explicit Runge-Kutta discretization in time
- Implemented an adaptive nonlinear solver to switch between *Newton-Rhapson* and *Gradient-Flow* for solving the nonlinear equations at each time step

Tearing of Viscoelastic Polymers — *May 2021 - Apr 2023*

Theoretical Component [**paper**]

- Developed a complete theoretical framework to explain the tearing of viscoelastic sheets subjected to *out of plane* tension
- Deployed the model to explain the celebrated experiments of Knauss on SBR (a hydrocarbon elastomer)

Numerical Component [**code**]

- Implemented full-field (3D) simulations for the *trousers fracture* test using non-conforming Crouzeix-Raviart finite elements in space and an adaptive implicit/explicit time stepper in time
- Implemented adaptive mesh refinement using open-source libraries `mmg3D`

Mechanical behavior of viscoelastic composites — *May 2020 - Sep 2021*

Theoretical Component [**paper**, **paper**]

- Developed a comprehensive analytical model to describe the effective behavior of viscoelastic composites containing two types of microstructures: (a) rubber filled with rigid inclusions and, (b) vacuous bubbles
- Derived analytical solutions in asymptotic limits of (a) slow loading, (b) fast loading and (b) when the rubber reduces to a Newtonian fluid

Numerical Component [**code**]

- Implemented an automatic and performant microstructure generator based on **Molecular Dynamics** in `NumPy/Numba` to generate spherical inclusions (rigid as well as vacuous)
- Implemented a high-order bubble-enriched finite element as **Abaqus UEL** and a 5th order Runge-Kutta solver in time
- Implemented automatic meshing, pre/post-processing to couple with the nonlinear solvers in Abaqus

Bending of Perforated Plates — *Mar 2019 - Aug 2020*

Theoretical Component [**paper**]

- Developed analytical solutions for the overall *pure bending* response of perforated plates with (a) perforations much smaller than the thickness, and (b) thickness much smaller than perforations
- Performed a comprehensive comparison with experiments
- Showed that the bending response is dominated by the porosity (void volume fraction) and has secondary effects from the shape and dispersion of pores

Numerical Component [**code**]

- Simulated the effect of hole shape, dispersion and porosity on the bending response of plates: considered ellipsoidal, circular, rectangular and square holes with a large range of void volume fraction

- Implemented a non-conforming FE scheme with periodic boundary conditions to determine the overall homogenized response of perforated plates
- Validated the scheme with full-field 3D analysis and performed a convergence study (h-refinement)

Macroscopic Response of Syntactic Foams *Nov 2018 - April 2019*

Theoretical Component [**paper**]

- Developed a phenomenological constitutive model for the overall (homogenized) response of syntactic foams
- Demonstrated the accuracy of the proposed model by comparing against experimental results on two types of syntactic foams: (a) PDMS elastomer, (b) Elastomer filled with glass-microballoons

Numerical Component [**code**]

- Implemented a mixed-FE formulation with periodic boundary conditions in `FEniCS` to determine the macroscopic response of a RVE/unit cell containing rigid particles and vacuous pores
- Implemented a nonlinear solver to determine the volume fraction of fractured/buckled microballoons under arbitrary applied loads

Macroscopic Response of Porous Elastomers *Aug 2017 - Oct 2018*

Theoretical Component [**paper**]

- Developed a closed-form constitutive model to describe the overall/homogenized response of porous elastomers
- Demonstrated the accuracy of the model by comparing it against full-field simulations for a variety of pore-shape, sizes, volume fractions (porosities) and distributions

Numerical Component [**code**]

- Implemented a mixed-FE formulation with periodic boundary conditions in `ABAQUS` to determine the macroscopic response of a RVE/unit cell containing vacuous pores
- Validated the numerical results against the proposed closed-form analytical solution and a WENO finite-difference solution

HONORS

- Awarded CEE Research Distinction Fellowship to present research work at WCCM/ECCOMAS 2020, USNC/TAM 2022, SES 2022, (Jan 2020 - Sep 2022)
- List of Teachers Ranked Excellent at UIUC (Dec 2017 and 2018)
- Invited Lecture on LaTeXon scientific writing (Mar 2017)
- Institute Silver Medal and Department Rank 1, IIT Guwahati (Jun 2015)
- Institute Merit Scholarship for securing Dept. Rank 1 for 5 consecutive semesters (Jan 2012 - Jan 2014)

COMPUTING PROJECTS

Generalized/Xtended Finite Element Method (GFEM/XFEM) [**report**, **code**] *Aug 2018 - Dec 2018*

- Implemented a 1D Generalized/Xtended Finite Element (FE) code in `python` using `Numpy` that implements polynomial and non-polynomial enrichment functions to solve problems with discontinuities
- Implemented a 1D FE code with hierarchical (legendre) basis functions to solve problems with cracks/material discontinuities

Newton-Multigrid FE Solvers for Incompressible Hyperelasticity [**report**, **code**] *Aug 2018 - Dec 2018*

- Implemented a 2D nonlinear FE solver for incompressible hyperelasticity with smoothed-aggregation multigrid (from `pyamg`) instead of `scipy.sparse.linalg.solve` inside a global Newton solver
- Achieved near optimal performance in linear solve with multigrid for a $n = 10,000$ degree-of-freedom system

High-Order FE methods [**report**, **code**] *Aug 2018 - Dec 2018*

- Implemented high-order $C1$ continuous FE basis (Argyris/Hermite) for solving biharmonic (4th order) differential equations
- Demonstrated optimal convergence of the FE solution using a h-refinement analysis

COURSES TAKEN AT UIUC

- Computational Mechanics: Numerical Methods (FE/FV/FD) for PDEs; Fast Algorithms and Integral Equations; Multigrid Methods; Generalized/Xtended FEM; Nonlinear Finite Elements; Computational Plasticity
- Deep Learning: Deep Generative and Dynamical Models; Machine Learning; Data Mining; Parallel Programming and Scientific Machine Learning
- Math: Advanced Finite Elements; Partial Differential Equations; Asymptotic Methods

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Google Scholar **List of Publications**