Indian Institute of Technology Delhi

School of Interdisciplinary Research (SIRe)

Project Proposal for Ph.D.

SIRe Project Number

2026-01-23

(will be assigned by SIRe)

Project Details (The research problem must clearly indicate the need for an interdisciplinary approach)	
Project Title	**AI-Guided Inverse Design of Auxetic Lattices with Uncertainty Quantification**
Project Summary (Minimum 500 and maximum 2000 characters)	Auxetic metamaterials — structures with a negative Poisson's ratio that expand laterally under tensile loading — offer exceptional mechanical advantages including superior energy absorption, enhanced indentation resistance, and tuneable stiffness. However, translating a known set of mechanical requirements (stiffness, Poisson's ratio, energy absorption) into an optimal auxetic lattice geometry remains a time-consuming trial-and-error process relying on thousands of finite element simulations. This project proposes a property-to-geometry inverse design framework driven by a Variational Autoencoder (VAE) augmented with Bayesian Uncertainty Quantification (UQ). The interdisciplinary challenge of this work is that mechanical target specifications always carry uncertainty from measurement error, material variability, and application tolerances — yet no existing machine-learning inverse design model accounts for this uncertainty or quantifies confidence in its geometry recommendations. The project addresses this gap by integrating expertise in auxetic mechanics and additive manufacturing with scientific machine learning and probabilistic modelling. A parametric FEA dataset of auxetic unit cell simulations (re-entrant, chiral, rotating-unit families) will be generated, mapping geometry descriptors to effective stiffness, Poisson's ratio, and energy absorption. A VAE will be trained to learn a smooth, searchable latent space of auxetic geometries coupled to property predictions. A Bayesian UQ layer (MC-Dropout or Deep Ensemble) will then quantify the confidence interval on each property prediction and identify 'fragile' designs sensitive to geometric perturbations. A robust inverse design algorithm will accept a target property distribution (mean ± tolerance) and return geometries that remain mechanically compliant across the full tolerance band. Top designs will be fabricated via FDM (TPU, PLA) and mechanically tested to validate that robust designs outperform non-robust counterparts under real manufacturing deviations.

Ph.D. Supervisors+
(Supervisor 1 and Supervisor 2 cannot be from the same department of IITD)

Role	Name of Faculty	Academic Unit in IITD/Institute/University	Email ID (Official)
Supervisor 1*	Dr. Kusum Meena	Department of Mechanical Engineering, IIT Delhi	kmeena@mech.iitd.ac.in
Supervisor 2	Prof. Souvik Chakraborty	Department of Applied Mechanics, IIT Delhi	souvik@am.iitd.ac.in

*Supervisor 1 must be from IIT, Delhi.
+All cells in this table are mandatory fields that need to be filled by faculty for consideration of proposal.
$The date of superannuation of supervisors should be at least three years from the date of registration of selected candidates.

Project requirements (Student qualifications, experience required, etc)
***The candidate will be shortlisted based on common shortlisting criteria decided by ScRC (SIRe)**

- B.Tech / M.Tech / M.E. in Mechanical Engineering, Aerospace Engineering, Civil Engineering, or closely related discipline with strong academic record (CGPA ≥ 7.5 or equivalent).
- Proficiency in finite element analysis (Abaqus, ANSYS, or equivalent); prior experience with parametric/scripted FEA simulations is highly desirable.
- Basic programming competency in Python (NumPy, pandas, matplotlib); willingness to learn PyTorch or TensorFlow for ML model training.
- Familiarity with additive manufacturing (FDM/SLA) and mechanical testing (UTM, DIC) is an advantage.
- Candidates with exposure to machine learning concepts (regression, neural networks, surrogate modelling) at UG/PG level or through coursework/MOOCs will be preferred.
- Strong problem-solving aptitude and interest in bridging computational mechanics with data-driven methods.

Source of fellowship/funding and project number (CSIR/UGC/DBT/ICMR/ICAR/NEET-PG/DST-INSPIRE/IRD/FITT Project details, if any)
Institute

Role of Faculty Members involved:	
Supervisor-1	Supervisor 1 (Dr. Kusum Meena) will lead the mechanical engineering components: auxetic lattice design and FEA dataset generation, AM fabrication and process optimisation, mechanical testing and experimental validation (UTM, DIC).
Supervisor-2	Supervisor 2 (Prof. Souvik Chakraborty) will lead the AI/ML components: VAE architecture design and training, Bayesian uncertainty quantification framework (MC-Dropout / Deep Ensemble), robust inverse optimisation formulation, and latent space analysis.

Note :-

1. **Approval from the respective DRC/CRC/ScRC of your Department/Centre/School will be required for using the "Full-time Institute Assistantship (Category-wise) (FIA)" for selecting the students in SIRe.**

2. **Declaration:- Faculty members, please ensure that you have at least 3 years of service left before superannuation along with adequate sitting space & lab facilities for the SIRe student.**

3. **PI/s are also encouraged to submit joint proposals with AIIMS, NII, JNU and institutes with which IITD has an existing MoU. If the Co-PI (Supervisor 2) is from outside IITD, kindly share his/her detailed CV.**

4. **If a research scholar is to be considered for selection under the project fellowship, then the project should have a minimum of two-year duration remaining.**

5. **A candidate applying with a valid JRF/INSPIRE/any national level fellowship should have at least two-year validity from the date of joining the Ph.D. program.**

6. **The third supervisor's name (if required) can be added only after the formation of Student Research Committee (SRC) subject to a strong recommendation of SRC and subsequent approval from the competent authority.**

7. **If Institute fellowship is being sought, then DRC approval of the parent department of Supervisor 1 is required at the time of selection.**