Gaurav Khanal

Saint-Étienne, France gaurav.khanal@etu.univ-cotedazur.fr +33 7 45 94 71 00

Website LinkedIn GitHub

PERSONAL SUMMARY

MSc Data Science & AI student focused on machine learning for biological and physical systems, with particular experience in biomedical signal processing, geometric and topological representation learning, and probabilistic modeling. Research spans biomedical signal processing, biomechanics, 3D geometric learning, uncertainty quantification, and scientific machine learning.

EDUCATION

MSc in Data Science and Artificial Intelligence *Sep. 2024—Aug. 2026*
Université Côte d'Azur, Sophia Antipolis, France
EFELIA Bourse d'Excellence 2025 *(Scholarship of Excellence)*

BA in Economics and Accounting *Aug. 2009—May 2013*
Westminster College, Fulton, Missouri, USA

PROFESSIONAL EXPERIENCE

Research Intern, *Predictive Constitutive Modeling of Atrial Appendage Tissue* *Apr. 2026—Present*
Mines Saint-Étienne | Centre Ingénierie et Santé | SAINBIOSE Lab Inserm U1059

- Developing mechanics-informed ML models to infer specimen-specific effective force response and constitutive behavior of atrial appendage (AA) tissue from projected 2D thickness maps and 3D surface mesh.
- Engineering 3D morphology and anisotropy descriptors from tissue meshes, including principal curvature morphology, Laplace–Beltrami spectral signatures, and fabric tensors.
- Extending the framework with point-cloud and mesh representation learning, including PointNet++, DGCNN, and mesh GNN baselines, to predict mechanical properties and constitutive parameters from 3D atrial tissue morphology.
- Investigating topology-aware descriptors for 3D tissue scans using topological data analysis, including persistent-homology-based summaries of multiscale shape, fold, ridge, and cycle structure, to assess whether topological features improve prediction of mechanical properties and constitutive parameters.
- Developing and benchmarking PointNet/PointNet++, DGCNN, MeshGraphNet, simplicial/Hodge, and $E(3)$–equinvariant topological neural networks to predict mechanically plausible force–stretch curves directly from 3D mesh and geometric representations.
- Developing a Bayesian probabilistic pipeline mapping registered 3D scans to force–stretch distributions and effective constitutive parameters, combining grouped nested validation, identifiability analysis, and uncertainty quantification.

RESEARCH EXPERIENCE

PERSIST: Topology-Guided Multiscale Domain Identification in Spatial Transcriptomics *Sep.—Dec. 2025*

- Developed PERSIST, an unsupervised topology-guided framework for spatial transcriptomics domain identification, addressing resolution sensitivity by inferring intrinsic tissue scales rather than relying on fixed clustering resolutions, smoothing radii, or neighborhood parameters.
- Constructed alpha-complex filtrations over tissue coordinates and used H_1 persistent homology birth-time distributions to identify topology-informed spatial scales associated with compartmentalization and boundary structure.
- Designed a Discrete Exterior Calculus-based multiscale stability field using 0-form smoothing, discrete gradients, topology-weighted local variation, bootstrap robust-core estimation, and Morse-like basin decomposition to separate stable domains, transition regions, and high-gradient boundaries.
- Applied PERSIST to breast cancer, human lymph node, and mouse brain spatial transcriptomics datasets, recovering biologically interpretable tissue organization supported by marker enrichment and H&E histology overlays.

Physics-Informed Image Registration for Hyperelastic Material Identification *Jan.—Apr. 2026*

- Developed a unified PINN framework for soft-tissue characterization that couples differentiable image registration with hyperelastic material-parameter identification, replacing the classical sequential digital image correlation (DIC) → displacement extraction → constitutive fitting pipeline.
- Integrated Ogden-model equilibrium constraints, explicit gravity loading, boundary-condition penalties, and multi-step reaction-force losses to regularize deformation fields and improve identifiability of material parameters.
- Generated synthetic tissue image sequences replicating the Gao–Desai porcine liver experiment, including gravity-induced pre-compression, tensile loading, natural-texture synthesis, and realistic imaging noise.

- Recovered Ogden parameters on synthetic validation with relative errors of 0.02% for μ and 0.006% for α, while implicitly resolving the zero-strain reference-state ambiguity that classical DIC pipelines estimate heuristically.

Graph Signal Processing for Characterization of Multipolar Electrograms in AF *Oct. 2025—Mar. 2026*

- Developed a geometry-aware graph signal processing framework for multipolar intracardiac electrograms (EGMs) in Atrial Fibrillation (AF), modeling PentaRay catheter electrodes as graph nodes and EGM recordings as graph signals over catheter geometry.
- Applied joint Short-Term Fourier Transform and Graph Fourier Transform analysis and graph total variation to detect rotor-proximal spatial discordance, showing that AF-band graph-time variation captured intermittent wavefront-collision patterns missed by per-channel temporal features.
- Proposed edge-flow extensions of catheter graph signals, enabling propagation dynamics to be interpreted through discrete differential operators and motivating Helmoltz-Hodge-style separation of planar/focal activation, rotor-like circulation and obstacle-related harmonic flow, providing a mechanistic route toward rotor-proximity indicators for AF ablation guidance.

Deep Learning for Full Waveform Inversion: Seismic Waveforms to Velocity Fields *May—Aug. 2025*

- Developed a data-driven FWI framework to learn the inverse map from multisource seismic shot gathers to subsurface velocity fields, targeting key limitations of conventional FWI: high computational cost, ill-posedness, and cycle skipping.
- Designed a hybrid Swin V2 Transformer + enhanced U-Net architecture combining long-range wavefield dependency modeling with high-fidelity spatial reconstruction of geological layers, faults, and heterogeneous structures.
- Built a scalable high performance OpenFWI training pipeline for 470,000 Vel/Fault/Style samples using memory-mapped data loading, GPU augmentations, and PyTorch DDP/AMP.
- Formulated a custom loss with inverse frequency weighting, and achieved best validation MAE of 63.27 m/s, with SSIM 0.8725–0.9188 across OpenFWI families; errors were concentrated mainly near sharp interfaces and fault boundaries.

SKILLS

Computer Languages: Python, R, MATLAB

Machine / Deep Learning Frameworks: PyTorch, JAX, Equinox, Flax, TensorFlow, scikit-learn

Scientific Computing & Geometry: NumPy, pandas, SciPy, CuPy, Gudhi, Trimesh, PyVista, ParaView

HPC, MLOps & Development: Grid5000, OAR, CUDA, PyTorch DDP, Git, Docker, MLflow, TensorBoard

Languages: English (C2—*fluent*), French (B1—*intermediate*), Spanish (A2—*elementary*)

CONTRIBUTIONS & COMPETITIONS

Co-winner (tied 1st place)—TopoBench Topological Deep Learning (TDL) Challenge 2026

- Developed an E(n)-equivariant topological neural network with graph-to-combinatorial-complex lifting, rank-wise message passing, geometric invariants, and equivariant coordinate updates; implemented and benchmarked the model within TopoBench on GraphUniverse and QM9.

Participant—NeurIPS 2025 EEG Foundation Challenge (Cross-Task & Cross-Subject EEG Decoding)

- Developed self-supervised EEG representation-learning pipelines using the HBN-EEG dataset (>3,000 participants, 128 channels, six cognitive tasks), investigating contrastive learning, redundancy-reduction objectives (Barlow Twins, VICReg), and domain-adversarial learning for robust cross-task and cross-subject neural representations.

SELECTED RESEARCH OUTPUTS

- Khanal, G. (2026). *PERSIST: Persistence-Guided Multiscale Domain Identification Using Stability Field Analysis in Spatial Transcriptomics*. Technical report / preprint. DOI: 10.13140/RG.2.2.24684.73606.
- Khanal, G. (2026). *A Physics-Informed Image Registration Framework for Hyperelastic Material Parameter Identification*. Technical report / preprint. DOI: 10.13140/RG.2.2.17896.84481.
- Khanal, G. (2025). *Deep Learning for Full Waveform Inversion: Exploring a Hybrid CNN–Transformer Approach to Reconstruct High-Fidelity Velocity Models from Seismic Waveforms*. Technical report / preprint. DOI: 10.13140/RG.2.2.20339.39205.

OTHER PROFESSIONAL EXPERIENCE

Senior Consultant, **Ernst & Young** *(Melbourne, Australia)*	Jul. 2021 – Apr. 2024
Senior Consultant, **Protiviti** *(USA & Australia)*	Jul. 2017 – Jun. 2021
Experienced Consultant, **PricewaterhouseCoopers** *(Kansas City, Missouri, USA)*	Sep. 2013 – Jul. 2017