

Shashwat Kumar

Postdoctoral Fellow, Department of Applied Mathematics and Statistics, Johns Hopkins University
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I develop statistical and machine learning methods for biological imaging, combining Riemannian shape analysis, probabilistic inference and computational imaging. Current work links cell and nuclear shape to gene expression in spatial transcriptomics and tracks synapses in longitudinal *in vivo* microscopy, with earlier applications to wearable sensing and human movement analysis.

Academic Appointments

Postdoctoral Fellow, Johns Hopkins University 2024–present

Department of Applied Mathematics and Statistics

Probabilistic inference and computational imaging for longitudinal *in vivo* synapse tracking; shape analysis methods linking cell morphology to gene expression in spatial transcriptomics.

Graduate Researcher, University of Virginia 2019–2024

Department of Systems Engineering

Machine learning, optimization and geometric data analysis for biomechanics, wearable sensing and biomedical applications.

Junior Research Fellow, National Centre for Biological Sciences 2017–2019

Simons Centre for the Study of Living Machines, Bangalore

Computer vision algorithms for segmentation, tracking and orientation estimation in dense biological imaging data.

Education

Ph.D., Systems Engineering, University of Virginia 2024

Coursework and research in statistical learning, optimization, geometric data analysis, Bayesian modeling and tensor methods.

B.E., Computer Science, BITS Pilani, Goa Campus 2014

Selected Research Contributions

KSTITCH: Linking Cellular Shape and Gene Expression in Spatial Transcriptomics

Collaborators: Vishaka Gopalan, Sridhar Hannenhalli (National Cancer Institute, NIH); Anuj Srivastava (Johns Hopkins University); P.-A. Absil (UCLouvain)

Developed size-independent, interpretable representations of cell and nuclear contours using tangent PCA on Kendall's shape manifold, and a canonical correlation framework linking shape modes to gene-expression programs measured in the same cells. In a reanalysis of about 2 million nuclei from a published siRNA screen, the representation recovered known nuclear-shape regulators with higher enrichment than an existing method. In melanoma spatial transcriptomics, it reproducibly linked fibroblast shape to tumor-associated activation and mesenchymal-like melanoma states to cell morphology across cohorts.

Bayesian In Vivo Tracking of Synapses via Joint Deconvolution and Diffeomorphic Registration

Collaborators: Dominic M. Padova, Michael I. Miller, Adam Charles, Richard L. Haganir, Austin Graves, Gabrielle Coste, Anuj Srivastava (Johns Hopkins University)

Developed a Bayesian generative model for longitudinal *in vivo* synapse tracking directly from raw two-photon microscopy data. The model jointly infers synapse locations, fluorescence dynamics and nonlinear tissue deformation, combining Poisson image formation, point spread function deconvolution and diffeomorphic registration.

SynTrack: Scalable Longitudinal Synapse Tracking

Collaborators: Michael I. Miller, Richard L. Haganir, Adam Charles, Austin Graves, Gabrielle Coste (Johns Hopkins University)

Developed a scalable maximum a posteriori tracker for large-scale longitudinal synapse imaging. SynTrack models anisotropic localization uncertainty and long-term occlusions with spatiotemporal graphs and achieves expert-level tracking accuracy.

Geometric Shape Analysis for Pediatric Neuromuscular Disease

Collaborators: Laura Barnes (University of Virginia); Anuj Srivastava (Florida State University)

Developed geometric representations of wearable sensor trajectories for objective motor assessment in Duchenne muscular dystrophy and spinal muscular atrophy, identifying interpretable, disease-specific movement patterns that correspond closely to clinical outcomes.

Optimization on Product Simplices via Smooth Geometric Reparameterization

Collaborator: P.-A. Absil (UCLouvain)

Developed smooth reparameterizations that turn constrained optimization over products of simplices into unconstrained Riemannian optimization, with applications to probabilistic tensor decomposition and functional data registration.

Publications

Journal Articles

- Kumar, Shashwat, Arafat Rahman, Robert Gutierrez, Sarah Livermon, Allison N. McCrady, Silvia Blemker, Rebecca Scharf, Anuj Srivastava, and Laura E. Barnes (2025). “A Shape-Based Functional Index for Objective Assessment of Pediatric Motor Function”. In: *PLOS ONE* 20.10, e0332383.
- Kumar, Shashwat, Debajyoti Datta, Guimin Dong, Lihua Cai, Mehdi Boukhechba, and Laura Barnes (2022). “Leveraging Mobile Sensing and Bayesian Change Point Analysis to Monitor Community-Scale Behavioral Interventions”. In: *ACM Transactions on Computing for Healthcare* 3.4, pp. 1–13.
- Tavakoli, Arash, Shashwat Kumar, Xiang Guo, Vahid Balali, Mehdi Boukhechba, and Arsalan Heydarian (2021). “HARMONY: A Human-Centered Multimodal Driving Study in the Wild”. In: *IEEE Access* 9, pp. 23956–23978.

Peer-Reviewed Conference Publications

- Datta, Debajyoti, Shashwat Kumar, Laura Barnes, and P. Thomas Fletcher (2022). “A Geometrical Approach to Finding Difficult Examples in Language”. In: *Proceedings of the ICML 2022 Workshop on Topological, Algebraic and Geometric Learning*. PMLR, pp. 86–95.
- Kumar, Shashwat, Robert Gutierrez, Debajyoti Datta, Sarah Tolman, Allison McCrady, Silvia Blemker, Rebecca J. Scharf, Mehdi Boukhechba, and Laura E. Barnes (2022). “Shape Analysis for Pediatric Upper Body Motor Function Assessment”. In: *Proceedings of the ACM International Symposium on Wearable Computers*, pp. 39–43.

Preprints

- Kumar, Shashwat, Dominic M. Padova, Binish Narang, Gabrielle I. Coste, Austin R. Graves, Richard L. Hugarir, Adam S. Charles, Michael I. Miller, and Anuj Srivastava (2026). *Bayesian In Vivo Tracking of Synapses using Joint Poisson Deconvolution and Diffeomorphic Registration*. arXiv: 2605.13455 [q-bio.QM].
- Kumar, Shashwat, Arafat Rahman, Anuj Srivastava, and P.-A. Absil (2026). *Smooth Reparameterizations of Functions on Simplicial Product Spaces: Applications to Probabilistic Tensor Decomposition and Functional Data Registration*. arXiv: 2608.02576.
- Kumar, Shashwat, Yingxiao Shi, Tuulia Vallius, Chi-Ping Day, P.-A. Absil, Anuj Srivastava, Sridhar Hannenhalli, and Vishaka Gopalan (2026). *KSTITCH Links Cellular Morphology and Gene Expression in Spatial Transcriptomics*. bioRxiv. DOI: 10.64898/2026.06.07.730714.
- Rahman*, Arafat, Shashwat Kumar*, Laura E. Barnes, and Anuj Srivastava (2026). *An Elastic Shape Variational Autoencoder for Skeleton Pose Trajectories*. arXiv: 2605.09231 [cs.CV].
- Kumar, Shashwat, Gabrielle I. Coste, Dasun Premathilaka, Richard L. Hugarir, Austin R. Graves, Adam S. Charles, and Michael I. Miller (2025). *Uncertainty-Gated Min-Cost Flows for In Vivo NanoScale Synaptic Plasticity Tracking*. bioRxiv. DOI: 10.1101/2025.10.10.681691.

* Equal contribution

Invited Talks

1. *Shape Representations of Cellular Morphology for In Situ Spatial Transcriptomics*
SIAM Conference on Mathematics of Data Science (MDS26), Salt Lake City, November 2026 (minisymposium talk, upcoming)
2. *KSTITCH Links Cellular Morphology and Gene Expression in Spatial Transcriptomics*
Department of Applied Mathematics and Statistics, Georgetown University
3. *In Vivo Tracking of Synaptic Plasticity*
Institute for Computational Medicine Retreat, Johns Hopkins University
4. *In Vivo Tracking of Synaptic Plasticity*
Center for Imaging Science Retreat, Johns Hopkins University
5. *Geometry Matters: Exploring Language Examples at the Decision Boundary*
ICML Workshop on Topology, Algebra, and Geometry in Machine Learning
6. *Shape Analysis for Pediatric Motor Quality Assessment*
ACM International Symposium on Wearable Computers

7. *An Introduction to Shape Analysis with Kendall Shape Space*

Indian Institute of Science Education and Research Kolkata

8. *Leveraging Mobile Sensing and Bayesian Change Point Analysis for Community-Scale Behavioral Interventions*

Link Lab, University of Virginia

Mentoring

- Undergraduate researcher, Bayesian computational imaging for longitudinal synapse tracking (third author on a collaborative manuscript).
- Neuroscience Ph.D. student, computational methods for synapse tracking and quantitative analysis of longitudinal *in vivo* imaging.
- Biomedical engineering graduate student, nonlinear image registration for longitudinal synapse imaging.

Teaching

- Teaching Assistant, DS 6040: Bayesian Machine Learning, University of Virginia
- Teaching Assistant, DS 6001: Practice and Applications of Data Science, University of Virginia

Professional Service

Reviewer for NeurIPS, ACM UbiComp, and ACM Transactions on Computing for Healthcare.

Technical Skills

- **Methods:** Bayesian inference, probabilistic modeling, statistical shape analysis, optimization on manifolds, differential geometry, inverse problems
- **Imaging and vision:** image registration, segmentation, object tracking, microscopy image analysis, computational anatomy
- **Software:** Python, PyTorch, PyMC, NumPy, SciPy, NetworkX, PyVista, MATLAB, Linux, Git

Industry Experience

Software Developer, RebelMouse

2014–2015

Built backend and web application components for a social media publishing platform at an early-stage startup.