

# Madhurima Nath

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Computational physicist and machine learning researcher specialising in artificial intelligence (AI) & machine learning (ML) solutions, statistical physics, and complex systems. Experience spans development of novel network analysis methods and implementation of large-scale machine learning systems, with particular focus on probabilistic modeling and scalable data analytics. Proven track record of developing production-ready ML solutions while leading cross-functional teams in engagements.

## EDUCATION & EXPERIENCE

<b>Senior Data Scientist</b> , Slalom, Inc., New York, NY	Sep 2024 – Present
<b>Data Scientist</b> , Slalom, Inc., New York, NY	Jul 2021 – Aug 2024
<b>Associate Data Scientist</b> , Slalom, Inc., New York, NY	Jan 2020 – Jun 2021
<b>Post-doctoral Research Assistant</b> , Virginia Tech, VA	Feb 2019 – Dec 2019
<b>Ph.D., Physics</b> , Virginia Tech, Blacksburg, VA	Dec 2018
<ul style="list-style-type: none"><li><i>Research Focus</i>: Complex systems analysis, Statistical physics, Network science, Community detection</li><li><i>Dissertation</i>: Application of Network Reliability to Analyse Diffusive Processes on Graph Dynamical Systems</li><li><i>US Patent</i> (US20210286859A1): System, method and computer readable medium for sensitivity of dynamical systems to interaction network topology</li></ul>	
<b>M.S., Physics</b> , Virginia Tech, Blacksburg, VA	May 2017
<b>M.Sc., Physics</b> , Indian Institute of Technology Delhi, New Delhi, India	May 2012
<ul style="list-style-type: none"><li><i>Thesis</i>: Study of Cold Atomic Condensates by Atomic Photon Interactions</li><li><i>Award</i>: Best Master of Science Thesis 2011-2012</li></ul>	
<b>B.Sc. (Hons.)</b> , Physics, University of Calcutta, Kolkata, India	May 2010
<ul style="list-style-type: none"><li><i>Minors</i>: Mathematics and Chemistry</li></ul>	

## MACHINE LEARNING RESEARCH & DEVELOPMENT (2020–PRESENT)

### Generative AI & Chatbot Proof of Concepts (POCs)

- Lead Data Scientist || Product Discovery Chatbot POC || Fortune 500 Financial Services Client**  
Architected a product discovery system on Databricks integrating Llama<sup>1</sup> with the LangChain agent framework, implementing MLflow pipelines. Developed a scalable solution in 2 months that achieved measurable improvements in information retrieval.
- Data Scientist || Interactive Q&A Chatbot || Healthcare Tech Startup**  
Developed a Q&A system using Anthropic Claude model on AWS<sup>2</sup> Bedrock, designed to extract insights from complex bio-pharma and med-tech datasets, in 6 weeks. Enhanced user interface design to improve accessibility and user satisfaction, resulting in a scalable solution for healthcare sector decision-making.
- Data Scientist || Knowledge-Based Chatbot for Sales || Fortune 500 Equipment Rental Firm** Engineered and deployed a knowledge-based chatbot using Retrieval Augmented Generation (RAG) with OpenAI GPT<sup>3</sup> and LangChain, improving document search efficiency and reducing response times to inquiries by 22%, delivering the first digital innovation initiative for the client.

### Data Science Projects

- Lead Data Scientist || NLP<sup>4</sup> for Safety Analytics || Fortune 500 Energy & Utility Client**  
Led the development & deployment of advanced NLP<sup>4</sup> pipelines on Azure Databricks, utilizing sentiment analysis and topic modeling to extract critical safety-related insights. Empowered the executive safety committee by providing data-driven analysis that refined organisational policies, directly contributing to improved employee safety and measurable reductions in incident frequency and severity.
- Lead Data Scientist || NLP<sup>4</sup> for e-Discovery Document Evaluation || Legal Services Client**  
Architected an e-discovery document classification system using Word2Vec document embeddings and SVM<sup>5</sup> classifiers on AWS<sup>2</sup> SageMaker, implementing an automated retraining pipeline that incrementally updates models based on human-reviewed samples. Demonstrated potential for reducing manual review efforts and costs through automated document classification and feedback-driven model improvements.
- Data Scientist || NLP<sup>4</sup> for Global Procurement || Fortune 500 Consumer Packaged Goods Company**  
Developed text classification pipeline to harmonise procurement product data into a standardised template using RandomForest classifier on Azure Machine Learning platform. Implemented MLOps best practices to incorporate addition of new products, updates to data labels and model re-training. Accelerated the data foundation roadmap by over a year and built scalable infrastructure design that improved data consistency and performance.

<sup>1</sup>Llama: Large Language Model Meta AI, <sup>2</sup>AWS: Amazon Web Services, <sup>3</sup>GPT: Generative pre-trained transformer, <sup>4</sup>NLP: Natural Language Processing, <sup>5</sup>SVM: Support Vector Machines

## DATA ENGINEERING EXPERIENCE

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### Data Migration to Salesforce || Nonprofit Organisation

- Successfully migrated 1TB of historical data to Salesforce through meticulously designed SQL stored procedures and optimised ELTL<sup>6</sup> pipelines in Azure Data Factory, ensuring comprehensive data integrity and seamless integration.
- Implemented advanced validation techniques that significantly reduced migration errors and enhanced overall data quality for enterprise-level data management.

### Data Lake Implementation on Snowflake || Nonprofit Organisation

- Maintenance and upgrade of data pipelines to load patient health and healthcare related data through parameterised SQL stored procedures in Snowflake Data Lake, ensuring comprehensive data integrity and seamless integration.
- Validated large-scale data quality checks and data transformation rules across multiple data resources providing and sharing patient health information.

### Network Predictive Maintenance Solution || Telecom Client

- Engineered a statistical radio frequency metrics analysis system with geographical clustering to identify at-risk infrastructure before failures occurred.
- Implemented automated SQL procedures processing 90-day network performance data, enabling targeted preventive maintenance validated across multiple regions.
- Projected \$8M+ in annual cost avoidance through reductions of ~30K customer calls and ~6K service visits, based on initial analysis later refined for regional variations.

## ACADEMIC RESEARCH EXPERIENCE

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### Post-doctoral Research Assistant, Virginia Tech, VA, (2019)

- Improved the complexity of evaluating Moore-Shannon network reliability on a graph (an NP<sup>7</sup>-hard problem) by combining Monte Carlo simulations with weak- and strong-coupling perturbative methods. [Technical paper](#)
- Implemented statistical approaches for community detection in large-scale weighted directed networks, achieving significant improvements over traditional methods.
- Applied computational methods to analyse international trade network dynamics from the United Nations (UN) Comtrade database, to identify crucial communities for preventing global pestilence distribution. [Community detection paper](#)

### Graduate Research Assistant, Virginia Tech, (2014-2018)

- Developed new approaches to Moore-Shannon network reliability formalism using Bernstein basis functions, Monte-Carlo simulations and statistical perturbative methods. [GitHub repo](#)
- Applied Moore-Shannon network reliability to predict final global states of graph dynamical systems, analyzing how interactions between individual node states and their connections determine final outcomes in practical applications. [PhD Dissertation](#)
- Simulated real-world epidemic outbreak and intervention scenarios on National Longitudinal Study of Adolescent to Adult Health dataset using network reliability, providing policymakers with improved estimates. Existing methods show about 50% over-estimation in number of infections. [Epidemic paper](#)
- Identified vulnerabilities within global food trade networks and accurately forecasted the impact of mitigating contagion conditions with approximately 96% precision to understand and mitigate the spread of pests. [Food trade paper](#)
- Developed an algorithm using concepts of Moore-Shannon network reliability to estimate the energy states of an interacting magnetic system, reducing the time complexity from  $O(n^2)$  to  $O(n)$ . [Ising model paper](#)

## TECHNICAL EXPERTISE

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### Computational & Data Processing

- Programming: Python, SQL, PySpark, R, Bash
- Distributed Computing: Apache Spark, PySpark, Databricks || Cloud Platforms: AWS<sup>2</sup>, Azure, GCP<sup>8</sup>,
- Version Control & CI/CD<sup>9</sup>: GitLab, GitHub, Azure DevOps, BitBucket, Docker (familiar)

### Machine Learning Analytics

- ML Frameworks: MLflow, LangChain, TensorFlow (familiar) || Data Tools: Delta Lake, Delta Lakehouse
- Areas: Statistical modeling, NLP<sup>4</sup>, LLMs<sup>10</sup> (Llama<sup>1</sup>, Anthropic Claude, OpenAI GPT<sup>3</sup>)

<sup>1</sup>Llama: Large Language Model Meta AI, <sup>2</sup>AWS: Amazon Web Services, <sup>3</sup>GPT: Generative pre-trained transformer, <sup>4</sup>NLP: Natural Language Processing, <sup>6</sup>ELTL: Extract, Load, Transform, Load, <sup>7</sup>NP: non-deterministic polynomial-time hardness, <sup>8</sup>GCP: Google Cloud Platform, <sup>9</sup>CI/CD: : Continuous Integration & Continuous Development, <sup>10</sup>LLM: Large Language Model

## PUBLICATIONS

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- Mishra, R., Eubank, S., **Nath, M.**, Amundsen, M., and Adiga, A. (2022, November). Community Detection Using Moore-Shannon Network Reliability: Application to Food Networks, In International Conference on Complex Networks and Their Applications (pp. 271-282). Cham: Springer International Publishing.
- Eubank, S., **Nath, M.**, Ren, Y., and Adiga, A. (2022). Perturbative methods for mostly monotonic probabilistic satisfiability problems. arXiv preprint arXiv:2206.03550.
- **Nath, M.**, et. al. (2019). Using network reliability to understand international food trade dynamics. In Complex Networks and Their Applications VII: Volume 1 Proceedings The 7th International Conference on Complex Networks and Their Applications COMPLEX NETWORKS 2018 7 (pp. 524-535). Springer International Publishing.
- **Nath, M.**, Ren Y., and Eubank, S. (2019). An approach to structural analysis using Moore-Shannon network reliability. In Complex Networks and Their Applications VII: Volume 1 Proceedings The 7th International Conference on Complex Networks and Their Applications COMPLEX NETWORKS 2018 7 (pp. 537-549). Springer International Publishing.
- **Nath, M.**, Ren, Y., Khorramzadeh, Y., and Eubank, S. (2018). Determining whether a class of random graphs is consistent with an observed contact network. Journal of theoretical biology. 440, 121-132.
- **Nath, M.**, and Eubank, S. (2018). Model selection for sequential designs in discrete finite systems using Bernstein kernels. arXiv preprint arXiv:1807.06661.
- Ren, Y., Eubank, S., and **Nath, M.**. (2016). From network reliability to the Ising model: A parallel scheme for estimating the joint density of states. Physical Review E, 94(4), 042125.
- **M. Nath**, et. al. (2015). A two-parameter method to characterize the network reliability for diffusive processes. In Complex Networks VI: Proceedings of the 6th Workshop on Complex Networks CompleNet 2015 (pp. 139-148). Springer International Publishing.
- Agarwala, A., **Nath, M.**, Lugani, J., Thyagarajan, K., and Ghosh, G. (2012). Fock-space exploration by angle resolved transmission through a quantum diffraction grating of cold atoms in an optical lattice. Physical Review A, 85(6), 063606.

## CONFERENCE PRESENTATIONS

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- **Invited Speaker:** Network reliability: a generic tool to explore diffusive processes on interacting systems, NASA Prebiotic Chemistry and Early Earth Environments (PCE3) Virtual Workshop 2022 Nano- to Cosmic- Studies of Complex Systems, University of Wisconsin Madison, Madison, WI, 20 Oct, 2022.
- Perturbative methods for estimating relative contributions to network reliability, SIAM (Society for Industrial and Applied Mathematics) Workshop on Network Science, Virtual Workshop, 13-15 Sep, 2022.
- Statistical mechanical applications of graph dynamical systems, Condensed Matter Seminar, Department of Physics, Virginia Tech, Blacksburg, VA, 30 Oct, 2017.
- Determining whether a particular contact network is consistent with a network model, 1st North American Social Networks Conference of the International Network for Social Network Analysis, Washington DC, 26-30 Jul, 2017.
- Network reliability: A novel measure to study the effects of network topology on the diffusive dynamics, Symposium for the Society of Young Network Scientists, NetSci 2017, Indianapolis, IN, 19-23 Jun, 2017.
- Network reliability: A measure to study diffusive dynamics on networks, Center for Soft Matter and Biological Physics Symposium 2017, Virginia Tech, Blacksburg, VA, 17-18 May 2017.
- Effects of network structure on propagation of infectious diseases, 33rd Annual Graduate Student Assembly Symposium and Exposition, Virginia Tech, Blacksburg, VA, 29 Mar 2017.
- Renormalisation group approaches for dynamics on irregular networks, American Physical Society (APS) March Meeting 2017, New Orleans, LA, 13-17 Mar, 2017.
- Diffusive dynamics on a network, Southeastern Section of the American Physical Society (SESAPS) Conference 2016, Charlottesville, VA, 9-12 Nov, 2016.
- Effects of network structure on epidemic modeling, Biocomplexity Institute Symposium 2016, Virginia Tech, Blacksburg, VA, 1 Nov, 2016.
- A two-parameter method to characterise the network reliability for diffusive processes, CompleNet 2015, New York City, NY, 25-27 Mar, 2015.
- Four-parameter characterisation of network reliability and analysis of critical point phenomenology, APS (American Physical Society) March Meeting 2015, San Antonio, TX, 2-6 Mar, 2015.

## PROFESSIONAL SERVICE & ACADEMIC ENGAGEMENT

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### Technical Review & Service

- Reviewer, NeurIPS: Machine Learning and Physical Sciences (2022, 2024)
- Reviewer, ICML<sup>9</sup>: Synergy of Scientific and Machine Learning Modeling (2023)
- Reviewer, Physical Review E (2022-Present)
- Industry Ambassador, Women in Network Science Society (2022-Present)
- Organiser of Women in Network Science Networks 2021 Conference (2021)

### Teaching & Mentorship

- Managed & mentored summer interns in advanced analytics and ML solutions, Slalom (2021-Present).
- Instructor of Record, Department of Physics, Virginia Tech (2018)  
Developed and delivered comprehensive physics curriculum for a 3-credit introductory physics course covering Waves, Acoustics & Optics to ~ 90 undergraduate students.
- Graduate Teaching Assistant, Department of Physics, Virginia Tech (2013-2015)
  - Supervised laboratory sessions for introductory physics courses (Kinematics & Electro-magnetism) and provided individualised student support.
  - Recognised as a top performing physics instructor for creating an effective learning environment.

### Invited Online Lectures

- **Speaker:** Insights into Data Engineering (Parts 1 & 2), Women Who Code San Francisco chapter, Jul 2021. [YouTube: Part 1](#) [YouTube: Part 2](#)
- **Speaker:** Exploring NLP<sup>4</sup> Fuzzy Matching Algorithms, Women Who Code, Apr 2021. [YouTube](#), [Medium article](#)
- **Panelist:** Statistics in Data Science Discussion, Women Who Code Statistics in Data Science Workshop Series, Mar 2021. [YouTube](#)
- **Speaker:** Regression & Predictions, Women Who Code Data Science: Statistics Workshop Series - Statistics in Data Science, Feb 2021. [YouTube](#), [Medium article](#)

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<sup>4</sup>NLP: Natural Language Processing, <sup>9</sup>ICML: International Conference on Machine Learning,