PRATEEK GARG

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Education

Indian Institute of Technology Bombay — Mumbai, India
B.Tech in Electrical Engineering and M.Tech in Machine Learning — *(Grade: **9.03/10.0**)*
Minor in Computer Science & Engineering — *Nov '20 – Jul '25 (Expected)*
Bachelor's & Master's Thesis Advisor : Prof. Sunita Sarawagi

Research Interests

My goal is to leverage tools from statistics and computer science to develop methods which are applicable across diverse real world applications, resilient to model imperfections and uncertainity. I am also interested in scalable and efficient ML systems that bridge algorithmic advancements with practical deployment.

Publications

1. **P. Garg**, L. Nagalapatti, S. Sarawagi, **"From Search to Sampling: Generative Models for Robust Algorithmic Recourse"** accepted to The Thirteenth International Conference on Learning Representations (ICLR 2025)
2. **P. Garg**, S. Sarawagi, **"Simple and Effective Fixes for Derivative-Free Diffusion Guidance"***(Manuscript in progress)*
3. S. Nasser, **P. Garg**, S. Pathak, K. Singhal, M. Meena, N. Gupte and A. Sethi, **"Utilizing Radiomic Feature Analysis for Automated MRI Keypoint Detection: Enhancing Graph Applications"** accepted to 11th International Conference on Bioimaging (BIOIMAGING 2024)
4. V. Prasad C, **P. Garg**, C. White, S. Nayak, P. Jain, A. Shameem, G. Ramakrishnan, **"Speeding up NAS with Adaptive Subset Selection"**, accepted at International Conference on Automated Machine Learning (AutoML 2024)

Research Experience

Inference-time Algorithms for Diffusion Models — *Sep '24 – Present*
Master's Thesis-I | Guide: Prof. Sunita Sarawagi — *CSE, IIT Bombay*

- ◇ **Introduction:** *Diffusion models have demonstrated strong potential in generating high-quality samples across various modalities. Reward guided sampling leverages a reward signal to guide the sampling process of pre-trained diffusion model. We examine the limitations of existing guidance methods and develop novel inference-time algorithms to address them*
- Developed a unified framework to analyze state-of-the-art inference algorithms for reward-guided diffusion sampling
- Investigated existing methods to pinpoint the causes of diversity loss, reward over-optimization, and sampling bias
- Demonstrated these limitations on synthetic and real datasets and proposed a simple strategy to improve the algorithms
- Working on strategies to effectively navigate the tradeoff between the expected rewards and *naturalness* of the samples

Diverse and Robust Algorithmic Recourse — *Mar '24 – Present*
Bachelor's Thesis-II (Paper) | Guide: Prof. Sunita Sarawagi — *CSE, IIT Bombay*

- ◇ **Introduction:** *Contemporary recourse methods recommend a single action against adverse outcomes from a decision making model and may even act adversarial to the model. In this project, we instead prioritize user flexibility by providing a distribution over low-cost, robust and plausible recourse actions, enabling more effective and personalized decision-making*
- Designed multiple synthetic datasets to visualize and study failure modes and tradeoffs in existing recourse methods
- Identified a proximal and plausible distribution over recourse instances and designed a strategy to learn this distribution
- Engineered a tabular data generator which demonstrated a state-of-the-art tradeoff between cost, plausibility and validity

Counterfactual Inference and Application to Algorithmic Recourse — *Aug '23 – Mar '24*
Bachelor's Thesis-I (Report) | Guide: Prof. Sunita Sarawagi — *CSE, IIT Bombay*

- ◇ **Introduction:** *A fast adoption of algorithmic methods across industries poses significant challenges. Algorithmic Recourse provides recommendations to individuals adversely affected by an automated system. We analyse the problem from the lens of counterfactual inference, when recommended actions have downstream effects which needs to be accounted for*
- Performed a thorough literature survey on Causal, Counterfactual inference and various applications to machine learning
- Formulated a recourse problem on time series data where current actions affect current as well as future covariates
- Conducted extensive experiments to validate the proposed methods and derived theoretical advantages over baseline

Image Registration using Graph Neural Networks *Jan '23 – Nov '23*
RnD Project (Paper) | Guide: Prof. Amit Sethi *EE, IIT Bombay*

- ◇ **Introduction:** *Image registration involves alignment of different images of the same scene or object, crucial for medical imaging. Classical methods which rely on techniques such as feature matching and intensity-based methods, do not perform well under non-linear complex deformations. We explore GNNs in conjunction with keypoint detection to execute this task*
- Created a novel dataset Medal-Retina consisting of retinal scans to evaluate models and algorithms for image registration
- Experimented with different techniques, augmenting node embeddings with structural information to enhance performance
- Proposed a novel scheme to create multi-scale graph representations to enhance the performance of SuperGlue network

Neural Architecture Search and Data Subset Selection *May '23 – Oct '23*
RnD Project (Code, Paper) | Guide: Prof. Ganesh Ramakrishnan *CSE, IIT Bombay*

- ◇ **Introduction:** *Best performing existing Neural Networks are hand-crafted. Neural architecture search (NAS) is a technique for automating the design process but often requires large computational resources, due to its expensive training and evaluation phases. In this project, we explore pruning based NAS methods and develop them to be more data-efficient*
- Worked on enhancing existing pruning-based Neural Architecture Search, experimenting with structured sparsity
- Incorporated adaptive subset selection to enhance the efficient use of data and obtained competitive results in the same

Professional Experience

Modem Firmware Intern | Qualcomm Technologies Inc. | WLAN Firmware team *May '23 – Jul '23*
WLAN Firmware team develops the low-level software with stringent latency requirements for Wi-Fi chips *Hyderabad, India*

- Improved the existing testing platform written using System-C library, developed for hardware-software co-design
- Utilised GDB to scout bugs and generalised a part of code, resulting progression of 30+ testcases on end-to-end testing
- Developed firmware for Wi-Fi ranging feature adhering to IEEE 802.11az standard to support many-to-one ranging

Scholastic Achievements

- Awarded the **Professor Ram Kumar Scholarship** to attend GAME-ARTS Conference held at IISc Banglore, India *(2024)*
- Accepted into the **Inter-Disciplinary Dual Degree Programme** at Center for Machine Intelligence and Data Science *(2023)*
- Secured an **All India Rank of 762** in JEE Advanced and **2388** in JEE Mains Examinations, among 2 million candidates *(2020)*
- Secured an **All India Rank of 200** in Kishore Vaigyanik Protsahan Yojana(KVPY) Examination, among 100K applicants *(2020)*
- Recipient of prestigious **KVPY Fellowship** by Department of Science and Technology, Government of India *(declined) (2020)*
- Ranked in the national **top 1% in NSEC** among 30,000+ candidates, qualified for Indian National Chemistry Olympiad *(2019)*

Teaching Experience

Head Graduate Teaching Assistant (Spring 2024) & Graduate Teaching Assistant (Spring 2023)
CS726 - Advanced Machine Learning *under Prof. Sunita Sarawagi* *CSE, IIT Bombay.*
Led a team of 10 TAs to manage a class of 200+ students, designed assignments and guided students in the coursework
Conducted full-length lectures on Causal Algorithmic Recourse (Spring '23) and Structure Prediction (Spring '24)

Undergraduate Teaching Assistant (Spring 2022)
MA106 - Linear Algebra *under Prof. Dipendra Prasad* *Mathematics, IIT Bombay.*
Assisted the instructors by grading papers, proctoring exams, mentoring students, conducting tutorials and help sessions

Selected Technical Projects

Local Augmentation for Graph Neural Networks *Aug '23 – Nov '23*
Course Project (Code, Presentation) | CS768 - Learning with Graphs | Guide: Prof. Abir De *CSE, IIT Bombay*

- Reproduced the results in the assigned paper and performed experiments to validate the method on other graph tasks
- Implemented a normalizing-flow based generative model to replace conditional VAE which demonstrated superior results
- Proposed a probablistic message-passing scheme based on the paper, to overcome over-smoothing observed in GNNs

Exploring Neural Ordinary Differential Equations *Aug '23 – Nov '23*
Course Project (Code, Report) | EE782 - Advanced Topics in Machine Learning | Guide: Prof. Amit Sethi *EE, IIT Bombay*

- Explored whether Neural ODEs as continuous depth model has advantage for various applications in machine learning
- Devised a custom autograd function in torch to implement a differentiable Neural ODE layer for easy experimentation
- Demonstrated the effectiveness of Neural ODEs on synthetic and real datasets for classification and generative tasks

Dense Retrieval System for Fact Checking Wikipedia Claims *Feb '24 – Mar '24*

Course Project (Code, Report) | CS728 - Deep Knowledge Representation | Guide: Prof. Soumen Chakrabarti *CSE, IIT Bombay*

- Built a retrieval system using BERT and FAISS to efficiently extract relevant evidence for claim verification from Wikipedia
- Finetune a BERT based verifier model to classify claims-evidence pair as Supported, Refuted, or Not Enough Info
- Optimized the entire pipeline through evidence selection and negative sampling, achieving strong recall and F1 scores

Automatic Differentiation Engine and Neural Network Library *May '23 – Jun '23*

Independent Project

- Built a pytorch like auto-grad engine in vanilla Python, implementing the backpropagation algorithm using BFS
- Utilised the engine to create a Neural Network Library and demonstrated effectiveness on various 2-dimensional datasets
- Implemented Kaiming initialization and Batch normalization layer to bypass gradient issues and achieved better results

Multi-armed Bandits and MDP Planning for Game Environments *Aug '23 – Nov '23*

Course Project (Code, Report) | CS747 - Reinforcement Learning | Guide: Prof. Shivaram Kalyanakrishnan *CSE, IIT Bombay*

- Implemented variants of Thompson sampling and KL-UCB algorithms for solving different multi-armed bandits problems
- Built a MDP planner module to produce optimal strategies for half-field football offence and a billiards game, using value iteration, linear programming, Howard's policy iteration and Monte-Carlo tree search

Structured Sparsity inducing Adaptive Optimizers *Jan '23 – May '23*

Course Project (Code, Report) | CS769 - Optimization in ML | Guide: Prof. Ganesh Ramakrishnan *CSE, IIT Bombay*

- Studied the notion of structured sparsity in context of neural networks and regularisation techniques to induce it in NNs
- Explored various regularisers utilising structured sparsity such as mixed ℓ_1/ℓ_2 norm and group min-max concave penality
- Experimented with different grouping of parameters and demonstrated the effectiveness at pruning skip connections

Rendera: Ray-tracing Engine in C++20 *May '22 – Jul '22*

Guided Project (Code) | Seasons of Code '22 | Web and Coding Club *ITC, IIT Bombay*

- Contributed to the mathematics subsystem, focusing on optimizing computations by leveraging SIMD instructions
- Utilised XSIMD which provides a cross-platform high level abstraction for SIMD intrinsics to implement a 4D vector class
- Utilised modern C++ features such as `constexpr` and `consteval` to improve runtime performance, reducing render time

Visual Explanations for Deep Neural Networks *Dec '21 – Jan '22*

Guided project (Code, Report) | Winter in Data Science'21 | Analytics Club *UGAC, IIT Bombay*

- Explored different ways of visualising Deep Neural Networks and reviewed literature on attribution methods for images
- Implemented attribution methods such as Saliency Maps, Occlusion Sensitivity Maps, and Class Activation Maps (CAMs)
- Demonstrated limitations of CAMs in localising multiple objects with different classes and objects with multiple instances

Technical Skills

Programming Languages: C/C++, Python, Julia, Java, Bash, Assembly{8051,8086}, MATLAB, VHDL
Libraries: Pytorch, PyTorch-Geometric, Tensorflow, Numpy, Pandas, SciPy, Seaborn, SymPy, Scikit-Learn, Matplotlib, Tensorflow
Software: Git, LaTeX, MATLAB, OpenCV, Octave, Docker, SSH, WSL, Quartus, GNU Radio, Jupyter, Keil, AutoCad

Key Coursework

Machine Learning: Advanced Machine Learning, Reinforcement Learning, Optimization for Machine Learning, Distributed Optimization, Online Learning and Optimisation, Learning with Graphs, Deep Knowledge Representation, Game Theory
Computer Science: Logic for Computer Science, Data Structures and Algorithms, Advanced Computer Architecture, Design and Analysis of Algorithms, Algorithmic Mechanism Design, Discrete Structures, Operating Systems, Computer Networks
Electrical Engineering: Matrix Computations, Markov Chains and Queuing Systems, Digital Systems, Signal Processing, Control Systems, Image Processing, Communication Systems & Networks, Digital Signal Processing, Microprocessors, Electronic Design
Mathematics: Calculus, Linear Algebra, Partial Differential Equations, Complex Analysis, Probability and Random Processes

Mentorship and Extracurriculars

Mentorship	• Machine learning (*Summer of Science*): **Guided four students** with suitable resources and material to build a theoretical understanding of the basics of Machine Learning, Deep Learning and Neural Networks • Python Programming: **Mentored 10+ freshmen** for programming contest; Also introduced version control
Technical	• **Secured 1st position** for Hostel-5 in Technical Inter-Hostel General Championship organised by ERC, IITB • Contributed to the **open-source project** xtensor-stack/xsimd, a SIMD intrinsics wrapper library in C++ • **Served as a reviewer** for India's Best UG Research Talents for ResCon, TechConnect 2024 by EnPower, IITB
Volunteering	• **Contributed articles** promoting sustainability to Parivartan-NSS, IITB's Wordpress blog with 125K+ hits • Volunteered for **Abhyuday, social body of IITB**, during the campaign to clean Versova Beach, Mumbai, India