Saurav Prakash

CONTACT INFORMATION

EEB 514, 3740 McClintock Ave
Electrical and Computer Engineering
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RESEARCH INTERESTS

Privacy-preserving and Secure Machine Learning, Federated Learning, Large-scale Distributed Learning, Coded Computing, Information Theory

EDUCATION

Doctor of Philosophy in Electrical and Computer Engineering — *Aug 2016 – present*
University of Southern California

Bachelor of Technology in Electrical Engineering — *Jul 2012 – May 2016*
Minor in Artificial Intelligence in Computer Science and Engineering
Indian Institute of Technology Kanpur

AWARDS AND ACHIEVEMENTS

- Qualcomm Innovation Fellowship 2021
- Qualcomm Innovation Fellowship 2019 finalist
- Most Novel Research Project Award, EE-599 (Deep Learning course, USC)
- USC Annenberg PhD Fellowship
- Princeton Gordon Wu PhD Fellowship offer
- Viterbi-India Program 2015
- Summer Undergraduate Research Grant for Excellence 2014 at IIT Kanpur
- Shri Singhasan Singh Scholarship 2015 for outstanding all round achievements at IIT Kanpur
- Institution of Engineering and Technology (IET) Scholarship 2015

PUBLICATIONS

Preprints and Journal Articles

- Saurav Prakash, Hanieh Hashemi, Yongqin Wang, Murali Annavaram and A. Salman Avestimehr. "Byzantine-Resilient Federated Learning with Heterogeneous Data Distribution," e-print https://arxiv.org/abs/2109.07706.
- Ahmed Roushdy Elkordy, Saurav Prakash, A. Salman Avestimehr. "Basil: A Fast and Byzantine-Resilient Approach for Decentralized Training," e-print https://arxiv.org/abs/2010.07541.
- Saurav Prakash, Sagar Dhakal, Mustafa Akdeniz, Yair Yona, Shilpa Talwar, Salman Avestimehr and Nageen Himayat. "Coded Computing for Low-Latency Federated Learning over Wireless Edge Networks," IEEE Journal on Selected Areas in Communications, 2021.
- Amirhossein Reisizadeh*, Saurav Prakash*, Ramtin Pedarsani, and Salman Avestimehr. "Coded Reduce: A Fast and Robust Framework for Gradient Aggregation in Distributed Learning," IEEE/ACM Transactions on Networking, 2021.
- Saurav Prakash*, Amirhossein Reisizadeh*, Ramtin Pedarsani, and Salman Avestimehr. "Coded Computing for Distributed Graph Analytics," IEEE Transactions on Information Theory, 2020.
- Amirhossein Reisizadeh, Saurav Prakash, Ramtin Pedarsani, and Salman Avestimehr. "Coded Computation over Heterogeneous Clusters," IEEE Transactions on Information Theory, 2019.

Conferences and Workshops

- Saurav Prakash, Sagar Dhakal, Mustafa Akdeniz, A. Salman Avestimehr, and Nageen Himayat. "Coded Computing for Federated Learning at the Edge," presented at the International Workshop on Federated Learning for User Privacy and Data Confidentiality, in Conjunction with ICML 2020 (FL-ICML'20).
- Saurav Prakash*, Amirhossein Reisizadeh*, Ramtin Pedarsani, and Salman Avestimehr. "Hierarchical Coded Gradient Aggregation for Learning at the Edge," IEEE International Symposium on Information Theory, 2020.
- Sagar Dhakal, Saurav Prakash, Yair Yona, Shilpa Talwar and Nageen Himayat. "Coded Federated Learning," IEEE Globecom Workshop on Wireless Edge Intelligence, 2019.

* denotes equal contribution

- Souvik Kundu*, Saurav Prakash*, Haleh Akrami, Peter Beerel, Keith Chugg. "A Pre-defined Sparse Kernel Based Convolution for Deep CNNs," IEEE Allerton Conference on Communication, Control, and Computing, 2019.
- Sagar Dhakal*, Saurav Prakash*, Yair Yona, Shilpa Talwar and Nageen Himayat. "Coded Computing for Distributed Machine Learning in Wireless Edge Network," IEEE VTC Fall Workshop on Vehicular Information Services for the Internet of Things, 2019.
- Amirhossein Reisizadeh*, Saurav Prakash*, Ramtin Pedarsani, and Salman Avestimehr. "Tree Gradient Coding," IEEE International Symposium on Information Theory, 2019.
- Saurav Prakash*, Amirhossein Reisizadeh*, Ramtin Pedarsani, and Salman Avestimehr. "Coded Computing for Distributed Graph Analytics," IEEE International Symposium on Information Theory, 2018.
- Amirhossein Reisizadeh, Saurav Prakash, Ramtin Pedarsani, and Salman Avestimehr. "Coded Computation over Heterogeneous Clusters," IEEE International Symposium on Information Theory, 2017.

Patent Applications

- Saurav Prakash, Sagar Dhakal, Yair Yona, Nageen Himayat and Shilpa Talwar. "Technologies for Distributing Iterative Computations in Heterogeneous Computing Environments," US Patent App. 16/368,716.
- Saurav Prakash, Sagar Dhakal, Yair Yona, Nageen Himayat and Shilpa Talwar. "Technologies for Distributing Gradient Descent Computation in a Heterogeneous Multi-access Edge Computing (MEC) Networks," US Patent App. 16/235,682.

Research Experience

Communications Sciences Institute, USC *Sep 2016 – present*

Mentor – Prof. Salman Avestimehr

- Byzantine Robust Federated Learning
  - Considered general Byzantine federated learning setting – non-IID data across clients, variability of Byzantine states, and general non-convex non-smooth optimization
  - Proposed DiverseFL, a novel sampling based approach that applies per client criteria for mitigating Byzantines in the general Byzantine federated learning setting
- Byzantine Robust Decentralized (Serverless) Learning
  - Considered the problem of Byzantine mitigation in the decentralized learning setting without any central coordinator
  - For the decentralized setting, proposed Basil, a fast and computationally efficient Byzantine robust algorithm that leverages a novel sequential, memory assisted and performance based criteria for training over a logical ring
- Coded Computing for Hierarchical Distributed Learning at the Edge
  - Developed a hierarchical gradient aggregation problem formulation for machine learning from data available at the client nodes, using reliable helper nodes for collecting messages from clients during training
  - Proposed two coded computing strategies – aligned repetition coding (ARC), and aligned minimum distance separable coding (AMC) – for mitigating straggling communication links from clients to helpers
- Coded Computing for Large-scale Distributed Learning
  - Proposed a Tree Gradient Coding framework and proposed CodedReduce scheme for fast and robust gradient aggregation in distributed learning, minimizing the overall computation latency for running distributed gradient descent algorithms
  - In linear regression and logistic regression experiments over Amazon EC2, CodedReduce achieves gains of up to 31× in the overall execution time over naive distributed implementation, and up to 7.9× over the benchmark Ring-AllReduce algorithm
- Coded Computing for Large-scale Graph Processing
  - Proposed a general distributed computing framework for Graph Analytics motivated by MapReduce
  - Characterized the optimal trade-off between Map computations and Shuffle load for the Erdos-Renyi model
  - Developed and implemented a coded distributed implementation of the PageRank algorithm using Amazon EC2, demonstrating gains of up to 50% over the naive PageRank for both synthetic and real-world graphs

  - Developed coding schemes for three other popular random graph models – random bipartite model, stochastic block model, and power law model

- Coded Computing for Large-scale Matrix Multiplication in Heterogeneous Settings
  - Proposed a two-step alternative formulation to the problem of minimizing the expected run-time in distributed matrix-vector multiplication in heterogeneous clusters
  - Developed a scalable method – Heterogeneous Coded Matrix Multiplication (HCMM) – for reliable matrix multiplication on cloud clusters with stragglers
  - Proved the asymptotic optimality of HCMM
  - Implemented HCMM using Amazon EC2, demonstrating gains of up to 61% over benchmark schemes

Applied Scientist Intern, Amazon *Summer 2021*
Mentors – Clement Chung, Christophe Dupuy, Rahul Gupta, Leo Long, Tanya Roosta

- Federated learning with Heterogeneous Model Architectures
  - Developed various strategies for efficient federated learning from edge users
  - Explored novel methods to enable federated learning with heterogeneous model architectures at the edge users

Intel Labs, Santa Clara *Summers 2018, 2019*
Mentors – Sagar Dhakal, Nageen Himayat, Shilpa Talwar

- Coded Computing for Federated Learning in Multi-access Edge Computing (MEC) networks
  - Proposed the first coded computing framework, CodedFedL, that injects structured coding redundancy into non-linear federated learning for mitigating stragglers and speeding up the training procedure in heterogeneous multi-access edge computing networks
  - Developed a tractable approach for finding optimal coding redundancy and the number of local data points that a client processes during training for minimizing the deadline time
  - Characterized the leakage in data privacy when clients share their local parity datasets with the server
  - Analyzed the convergence rate and iteration complexity of CodedFedL, by treating CodedFedL as a stochastic gradient descent algorithm
  - In numerical experiments using practical network parameters and benchmark datasets, CodedFedL provided gains of up to 15× in comparison to benchmark schemes

Viterbi-India Program, USC *May 2015 – Jul 2015*
Mentor – Prof. Salman Avestimehr

- Towards Faster Algorithms for Processing Large Data on Graphs
  - Studied spectral graph theory and its application in signal processing of graph data – cut-off frequency, optimal sampling and bandlimited interpolation
  - Explored existing semi-supervised and active learning methods for data on graphs
  - Proposed a Random Jump model based on Graph Laplacian for sampling with low time complexity

Undergraduate Project, Multimedia Wireless Networks Group, IIT Kanpur
Mentor – Prof. Aditya K. Jagannatham

- Scheduling for Efficient Utilization of Time Resource in Wireless Networks
  - Worked on the problem of user scheduling for efficient wireless resource utilization, under resource allocation fairness constraints
  - Proposed two opportunistic schemes for scheduling users in a time slotted system with wireless Rayleigh-fading channel
  - Simulations predicted stochastically improved performance compared to Round Robin scheme alongside satisfaction of any arbitrary time resource allocation fairness constraints

Summer Undergraduate Research Grant for Excellence, IIT Kanpur *May 2014 – Jul 2014*
Mentor – Prof. Aditya K. Jagannatham

- Channel Estimation and Capacity in MIMO Wireless Communication Systems

- Analyzed capacity lower bound for a MIMO system obeying Block-Fading law using LMMSE estimator for channel estimation at the receiver
- Obtained an optimal number of transmit antennas for optimizing the capacity lower bound

Reviewer Service

- Conferences and Workshops: IEEE International Symposium on Information Theory (ISIT), IEEE Information Theory Workshop (ITW)
- Journals: IEEE Journal on Selected Areas in Communications, IEEE Transactions on Information Theory, IEEE Journal on Selected Areas in Information Theory, IEEE Transactions on Communications

Selected Coursework

- **Algorithms and Artificial Intelligence**: Deep Learning, Data Structure and Algorithms, Fundamentals of Computing, Machine Learning for Computer Vision, Artificial Intelligence Programming
- **Mathematics**: Applied Stochastic Processes, Real Analysis, Probability and Statistics, Linear Algebra, Complex Analysis, Partial Differential Equations, Random Processes in Engineering
- **Communication and Signal Processing**: Error Correcting Codes, Wireless Communications, Information Theory, Topics in Cryptography and Coding, Digital Signal Processing, Digital Communication Networks

Technical Skills

- Python, Amazon Web Services, C, C++, HTML, PHP, MYSQL, MATLAB, AutoCAD, XAMPP

Positions of Responsibility

- **Student Guide, Counselling Service, IIT Kanpur:** Guided 6 students during their freshman year; helped them to adjust to the new academic and social environment. Assisted Counselling Service in organising Orientation Programme for freshmen and other student activities
- **Ambassador Caller, Alumni Contact Program, IIT Kanpur:** Helped reconnect the institute alumni back to their almamater; encouraged them to donate to their institute, both monetarily and in kind. Mentored a team of 5 students during Summer'13
- **Secretary, Fine Arts Club, IIT Kanpur:** Coordinated and managed club budget and material availability; organised workshops like Wood Carving, Sand Art and Speed Art; managed year round club activities

Extracurricular Activities

- Senior Diploma in the Indian classical instrument Tabla from Prayag Sangeet Samiti
- Five year accomplishment Ankan Bivakar in Painting under Bangiya Sangeet Parishad
- First position in freshman competition of Robotics club in Takneek – interhall technical festival of IIT Kanpur