Shashanka Ubaru

201 E 24th Street, POB 3.134
University of Texas, Austin, TX, USA 78712
✉ *Shashanka.Ubaru@ibm.com*
shashankaubaru.github.io

Research Interests

Numerical linear and tensor algebra, machine learning, artificial intelligence, quantum computing, coding theory applications, approximation theory and algorithms.

Positions

2018 - present **IBM Research**, *Yorktown Heights/Austin*, USA.
Senior Research Scientist — May, 2022 - present
Research Staff Member — Jan, 2020 - May, 2022
Goldstine Postdoctoral Fellow — Aug, 2018 - Dec, 2019

2022 - present **Oden Institute**, *University of Texas at Austin*, TX, USA.
Lecturer — Jan, 2024 - present
Visiting Researcher — June, 2022 - present

2013 - 2018 **University of Minnesota**, *Minneapolis*, MN, USA.
Research Assistant, Department of Computer Science. — Sep, 2013 - May, 2018

2016 & 2017 **Lawrence Berkeley National Laboratory**, *Berkeley*, CA, USA.
Research Intern, Neural Systems and Data Science Lab — June - Aug, 2017
Research Intern, Scientific Data Management group — May - Aug, 2016

2013 **Seagate Technology**, *Shakopee*, MN, USA.
Signal Processing Intern — May - Aug, 2013

2011 - 2012 **Raman Research Institute**, *Bangalore*, India.
Visiting Research Student — June, 2011 - Aug, 2012

Education

2012-18 **University of Minnesota**, *Minneapolis*, MN, USA.
Ph.D. Computer Science — May 2018
Advisor: Yousef Saad
Thesis: *Algorithmic advances in learning from large dimensional matrices and scientific data*

M.S. Computer Science — October 2015
M.S. Electrical Engineering — November 2014
Advisors: Yousef Saad and Arya Mazumdar
Thesis: *Randomized techniques for matrix decomposition and estimating the approximate rank of a matrix*

2008-12 **M.S. Ramaiah Institute of Technology**, *Bangalore*, India.
B.Eng. Electronics and Communication

Publications

Journal articles

[10] *Representation of the Fermionic Boundary Operator*.
I.Y. Akhalwaya, Y.H. He, L. Horesh, V. Jejjala, W. Kirby, K. Naidoo, and **S. Ubaru**
Physical Review A, volume 106, 022407, 2022.

[9] *Dynamic graph and polynomial chaos based models for contact tracing data analysis and optimal testing prescription*.
S. Ubaru, G. Cohen, and L. Horesh
Journal of Biomedical Informatics, Novel Informatics Approaches to COVID-19 Research, 122, 103901, 2021.

[8] *Spectrum-Adapted Polynomial Approximation for Matrix Functions with Applications in Graph Signal Processing*.
L. Fan, D. Shuman, **S. Ubaru**, and Y. Saad
Algorithms, Special Issue: Efficient Graph Algorithms in Machine Learning, 13(11), 295, 2020.

[7] *Sampling and multilevel coarsening algorithms for fast matrix approximations*.
S. Ubaru and Y. Saad
Numerical Linear Algebra with Applications 26.3 : e2234, 2019.

[6] *Fast estimation of* $\mathtt{tr}(f(A))$ *via Stochastic Lanczos Quadrature*.
S. Ubaru, J. Chen, and Y. Saad
SIAM Journal on Matrix Analysis and Applications (SIMAX), 38(4), 1075–1099, 2017.

[5] *Low rank approximation and decomposition of large matrices using error correcting codes*.
S. Ubaru, A. Mazumdar, and Y. Saad
IEEE Transactions on Information Theory, 63(9), 5544–5558, 2017.

[4] *Formation enthalpies for transition metal alloys using machine learning*.
S. Ubaru, A. Miedlar, Y. Saad, and J R. Chelikowsky
Physical Review B, (Vol.95, No.21), 2017.

[3] *Fast estimation of approximate matrix ranks using spectral densities*.
S. Ubaru, Y. Saad, and A.-K. Seghouane
Neural Computation, 29(5):1317–1351, 2017.

[2] *Improving the Incoherence of a Learned Dictionary via Rank Shrinkage*.
S. Ubaru, A.-K. Seghouane, and Y. Saad
Neural Computation, 29(1):263–285, 2017.

[1] *Displaying gray scales by cross pairing select and data voltages in multi-line addressed LCD*.
S. Ubaru and T.N. Ruckmongathan
IEEE Journal of Display Technology, 8(11), 669–677, 2012.

Conference proceedings

[20] *Asynchronous Randomized Trace Estimation*.
V. Kalantzis, **S. Ubaru**, G. Kollias, C.W. Wu, and L. Horesh.
International Conference on Artificial Intelligence and Statistics (AISTATS), 2024.

[19] *Topological Data Analysis on Noisy Quantum Computers*.
I. Akhalwaya*, **S. Ubaru***, K. Clarkson, M. Squillante, V. Jejjala, Y. He, K. Naidoo, V. Kalantzis, and L. Horesh.
International Conference on Learning Representations (ICLR), 2024. *Oral presentation,* 1.2% *of submissions*

[18] *Solving Sparse Linear Systems via Flexible GMRES with In-Memory Analog Preconditioning*.
V. Kalantzis, M.S. Squillante, C. W. Wu, A. Gupta, **S. Ubaru**, T. Gokmen, and L. Horesh
IEEE High Performance Extreme Computing (HPEC), 2023.

[17] *Quantum Graph Transformers*.
G. Kollias, V. Kalantzis,T. Salonidis, and **S. Ubaru**
International Conference on Acoustics, Speech, and Signal Processing (ICASSP), 2023.

[16] *Accelerating matrix trace estimation by Aitken's* Δ^2 *process*.
V. Kalantzis, G. Kollias, **S. Ubaru**, and T. Salonidis
International Conference on Acoustics, Speech, and Signal Processing (ICASSP), 2023.

[15] *Efficient Scaling of Dynamic Graph Neural Networks*.
V. Chakaravarthy, S. Pandian, S. Raje, Y. Sabharwal, T. Suzumura, and **S. Ubaru**
Supercomputing (SC21), 2021.

[14] *Analysis of stochastic Lanczos quadrature for spectrum approximation*.
T. Chen, T. Trogdon, and **S. Ubaru**
International Conference on Machine Learning (ICML), 2021. *Long presentation*

[13] *Projection techniques to update the truncated SVD of evolving matrices*.
V. Kalantzis, G. Kollias, **S. Ubaru**, A. Nikolakopoulos, L. Horesh, and K.L. Clarkson
International Conference on Machine Learning (ICML), 2021.

[12] *Sparse graph based sketching for fast numerical linear algebra*.
D. Hu, **S. Ubaru**, A. Gittens, K. Clarkson, L. Horesh, and V. Kalantzis
International Conference on Acoustics, Speech, and Signal Processing (ICASSP), 2021.

[11] *Dynamic Graph Convolutional Networks Using the Tensor M-Product*.
O. Malik, **S. Ubaru**, L. Horesh, M. Kilmer, and H. Avron
SIAM International Conference on Data Mining (SDM), 2021.

[10] *Multilabel Classification by Hierarchical Partitioning and Data-dependent Grouping*.
S. Ubaru, S. Dash, O. Gunluk, and A. Mazumdar
Advances in Neural Information Processing Systems (NeurIPS), 2020.

[9] *Spectrum-Adapted Polynomial Approximation for Matrix Functions*.
L. Fan, D. Shuman, **S. Ubaru**, and Y. Saad
International Conference on Acoustics, Speech, and Signal Processing (ICASSP), 2019.

[8] *Find the dimension that counts: Fast dimension estimation and Krylov PCA*.
S. Ubaru, A.-K. Seghouane, and Y. Saad
SIAM International Conference on Data Mining (SDM), 2019.

[7] *Spectral Sums Beyond Fast Matrix Multiplication: Algorithms and Hardness*.
C. Musco, P. Netrapalli, A. Sifford, **S. Ubaru**, and D. P. Woodruff
Innovations in Theoretical Computer Science (ITCS), 2018.

[6] $UoI\text{-}NMF_{cluster}$*: A Robust Nonnegative Matrix Factorization Algorithm for Improved Parts-Based Decomposition and Reconstruction of Noisy Data*.
S. Ubaru, K. Wu, and K. E. Bouchard
IEEE International Conference on Machine Learning and Applications (ICMLA), 2017.
Best Paper Award.

[5] *Union of Intersections (UoI) for Interpretable Data Driven Discovery and Prediction*.
K. E. Bouchard, A. F. Bujan, F. Roosta-Khorasani, **S. Ubaru**, Prabhat, A. M. Snijders, J.-H. Mao, E. F. Chang, M. W. Mahoney, and S. Bhattacharyya
Advances in Neural Information Processing Systems (NeurIPS), 2017.

[4] *Multilabel Classification with Group Testing and Codes*.
S. Ubaru and A. Mazumdar
International Conference on Machine Learning (ICML), 2017.

[3] *Fast methods for estimating the Numerical rank of large matrices*.
S. Ubaru and Y. Saad
International Conference on Machine Learning (ICML), 2016.

[2] *Group testing schemes from low-weight codewords of BCH codes*.
S. Ubaru, A. Mazumdar, and A. Barg
IEEE International Symposium on Information Theory (ISIT), 2016.

[1] *Low rank approximation using error correcting coding matrices*.
S. Ubaru, A. Mazumdar, and Y. Saad
International Conference on Machine Learning (ICML), 2015.

Book chapters

[2] *Quantum Computing Algorithms For Decision Making Under Uncertainty*.
L. Horesh, K. Clarkson, V. Kalantzis, M. Squillante, **S. Ubaru**, and A. Abboud
Air Force Research Lab Technical Report, AFRL-RI-RS-TR-2021-121, 2021.

[1] *Applications of trace estimation techniques*.
S. Ubaru and Y. Saad
High Performance Computing in Science and Engineering, LNCS book series, vol. 11087, ch. 2, pp 19–33, 2018.

Workshop papers and posters

[5] *Topological Data Analysis on Noisy Quantum Computers*.
S. Ubaru, I Akhalwaya, K. Clarkson and L. Horesh
Quantum Information Processing (QIP), 2023.

[4] *On Quantum Algorithms for Random Walks in the Nonnegative Quarter Plane*.
V. Kalantzis, M. S. Squillante, **S. Ubaru**, and L. Horesh
Workshop on Mathematical performance Modeling and Analysis (MAMA), 2022.

[3] *Multilabel prediction in log time and data-dependent grouping*.
S. Ubaru, S. Dash, O. Gunluk, and A. Mazumdar
NeurIPS - Workshop on Information Theory and Machine Learning, 2019.

[2] *Tensor graph neural networks for prediction on time varying graphs*.
O. Malik, **S. Ubaru**, L. Horesh, M. Kilmer, and H. Avron
NeurIPS - Workshop on Graph Representation Learning, 2019.

[1] *Union of Intersections (UoI) for interpretable data driven discovery and prediction in neuroscience*.
K. E. Bouchard, P. Sachdeva, S. Bhattacharyya, M. Balasubramanian, and **S. Ubaru**
Computational and Systems Neuroscience (Cosyne), 2019.

Preprints

[9] *Combinatorial Multi-armed Bandits: Arm Selection via Group Testing*.
A. Mukherjee, **S. Ubaru**, K. Murugesan, K. Shanmugam, Ali Tajer, 2024.

[8] *Counting Triangles of Graphs via Matrix Partitioning*.
G. Kollias, V. kalantzis, L. Horesh, **S. Ubaru**, and P. Traganitis, 2023.

[7] *Single-Pass Top-N Subgraph Centrality of Graphs via Subspace Projections*.
V. Kalantzis, G. Kollias, **S. Ubaru**, L. Horesh and N. Abe, 2023

[6] *Capacity Analysis of Vector Symbolic Architectures*.
K.L. Clarkson, **S. Ubaru**, and E. Yang, 2023.

[5] *Randomized matrix-free quadrature for spectrum and spectral sum approximation*.
T. Chen, T. Trogdon, and **S. Ubaru**, 2022.

[4] *PCENet: High Dimensional Surrogate Modeling for Learning Uncertainty*.
P.F. Shustin, **S. Ubaru**, V. Kalantzis, L. Horesh, and H. Avron, 2022.

[3] *Quantum Topological Data Analysis with Linear Depth and Exponential Speedup*.
S. Ubaru, I. Akhalwaya, M. Squillante, K. Clarkson, and L. Horesh, 2021.

[2] *Unsupervised Hierarchical Graph Representation Learning with Variational Bayes*.
S. Ubaru and J. Chen, 2020.

[1] *Provably convergent acceleration in factored gradient descent with applications in matrix sensing*.
T Ajayi, D Mildebrath, A. Krylidis, **S. Ubaru**, G. Kollias, and K. E. Bouchard, 2019.

Patents

[25] *P202203839 - Efficient look-up for vector symbolic architectures (VSA)*.
T. Gokmen, V. Kalantzis, P. Ram, C. Wu, K. Clarkson, L Horesh, and **S. Ubaru**. (filed)

[24] *P202302321 - An asynchronous modeled system for fault-tolerant environments*.
L Horesh, V. Kalantzis, G Kollias, **S. Ubaru**, and C. Wu. (filed)

[23] *P202203693- Privacy-preserving graph analytics on hybrid cloud environments*.
V. Kalantzis, L. Horesh, **S. Ubaru**, and G. Kollias,. (filed)

[22] *P202204543 - A system to update the most influential nodes of dynamic graphs*.
V. Kalantzis, G Kollias, **S. Ubaru**, L Horesh, and N Abe. (filed)

[21] *P202204563 - Quantum Graph Transformers*.
G. Kollias, V. Kalantzis,T. Salonidis, and **S. Ubaru**. (filed)

[20] *P202203488- Aitken acceleration for estimating electronic structures of materials and the like*.
V. Kalantzis, G. Kollias, **S. Ubaru**, and T. Salonidis. (filed)

[19] *P202105416- Processing sparse linear systems using distributed resources*.
V. Kalantzis, **S. Ubaru**, and L. Horesh. (filed)

[18] *P202202073 - Solving systems of linear equations using mixed precision*.
T. Gokmen, V. Kalantzis, **S. Ubaru**, and L. Horesh. (filed)

[17] *P202200441 - Polynomial Chaos Expansion Neural Network*.
P. Fink, **S. Ubaru**, H. Avron, V. Kalantzis, and L. Horesh. (filed)

[16] *US20240028939A1 - Linear-depth quantum system for Topological Data Analysis*.
I. Akhalwaya, **S. Ubaru**, K. Clarkson, M. Squillante, V. Kalantzis, and L. Horesh. (pending)

[15] *US20240020565A1 - Quantum circuit for estimating matrix spectral sums*.
S. Ubaru, I. Akhalwaya, K. Clarkson, M. Squillante, V. Kalantzis, and L. Horesh. (pending)

[14] *US20240020564A1 - Quantum circuits for matrix trace estimation*.
S. Ubaru, K. Clarkson, I. Akhalwaya, M. Squillante, V. Kalantzis, and L. Horesh.(pending)

[13] *US20240020563A1 - Quantum circuit for transformation of mixed state vectors*.
I. Akhalwaya, **S. Ubaru**, K. Clarkson, M. Squillante, V. Kalantzis, and L. Horesh. (pending)

[12] *US20240022247A1 - Quantum circuit for pairwise testing*.
S. Ubaru, I. Akhalwaya, K. Clarkson, M. Squillante, V. Kalantzis, and L. Horesh.(pending)

[11] *US20240037304A1 - Quantum circuit for simulating boundary operator*.
I. Akhalwaya, Y. He, L. Horesh, V. Jejalla, W. Kirky, K. Naidoo, and **S. Ubaru** (pending)

[10] *US20230410113A1 - Detecting network patterns using random walks*.
K.P. Onak, **S. Ubaru**, A. Abboud, and T. Suzumura. (pending)

[9] *US20230195457A1 - Hardware acceleration with preconditioners*.
V. Kalantzis, L. Horesh, and **S. Ubaru**. (pending)

[8] *US20220382831A1 - Projection-based techniques for updating SVD in evolving datasets*.
V. Kalantzis, G. Kollias, **S. Ubaru**, L. Horesh, and K. Clarkson. (pending)

[7] *US20220300575A1 - Determining triangles in graph data structures using crosspoint array*.
V. Kalantzis, **S. Ubaru**, L. Horesh, and H. Avron. (pending)

[6] *US11500963B2 - Fast PCA of evolving data using analog crossbar array*.
S. Ubaru, V. Kalantzis, L. Horesh, M. Squillante, and H. Avron.

[5] *US11790033B2- Accelerated quasi-newton methods on analog crossbar hardware*.
V. Kalantzis, **S. Ubaru**, L. Horesh, H. Avron, and M. Onen.

[4] *US11520855B2 - Matrix sketching using analog crossbar architectures*.
L. Horesh, M. Onen,H. Avron, T. Gokmen, **S. Ubaru**, and V. Kalantzis.

[3] *US11657312B2 - Short-depth quantum amplitude estimation without eigenstate collapse*.
I. Akhalwaya, K. Clarkson, L. Horesh, M. Squillante, **S. Ubaru**, and V. Kalantzis.

[2] *US11379758B2 - Automatic multilabel classification using machine learning*.
S. Ubaru, S. Dash, O. Gunluk, A. Mazumdar and L. Horesh.

[1] *US11386507B2 - Tensor-based predictions from analysis of time-varying graphs*.
O. Malik, **S. Ubaru**, L. Horesh, M. Kilmer, and H. Avron.

Presentations

2023 *Dynamic graph representation learning using tensor algebra*
- UTD CS Colloquium, University of Texas Dallas
Topological data analysis on noisy quantum computers
- QuSoft, CWI, Amsterdam, The Netherlands
- QIP 2023 conference, Ghent, Belgium
Algorithms for estimating spectral sums for large matrices
- Rachel Ward group, University of Texas at Austin

2022 *Industry Panelist*
- SIAM Conference on Mathematics of Data Science (MDS22), San Diego
Towards quantum advantage on noisy computers
- Google Research, Bengaluru
Dynamic graph representation learning using tensor algebra
- Oden Institute Seminar Series, University of Texas at Austin
- SIAM Conference on Mathematics of Data Science (MDS22), San Diego
- Data Science group, University of California, San Diego.
Multilabel Classification by Hierarchical Partitioning and Grouping
- RISE workshop, Austin, TX
Quantum Topological Data Analysis with Linear Depth and Exponential Speedup
- Quantum Information Group, University of Texas at Austin
- Quantum computing course, Columbia University, New York

2021 *Into another dimension - a new tensor algebra for learning on dynamic graphs*
- Seminar at University of Albany, NY
Algorithms for estimating spectral sums for large matrices
- Oden Institute Seminar Series, University of Texas at Austin
Novel Tensor Framework for Data Representation and Compression
- SIAM Conference on Computational Science and Engineering (CSE21)

2020 *Multilabel Classification by Hierarchical Partitioning and Data-dependent Grouping*
- Neural Information Processing Systems (NeurIPS) Virtually held
Novel tensor framework for model reduction and neural networks
- ICERM: Workshop on Algorithms for Dimension and Complexity Reduction, Brown University, RI

2019 *Tensor graph neural networks for prediction on time varying graphs*
- NeurIPS: Workshop on Graph Representation Learning, Vancouver, Canada
Multilabel prediction in log time and data-dependent grouping
- NeurIPS: Workshop on Information Theory and Machine Learning, Vancouver, Canada
Spectrum approximation by Lanczos Quadrature and Preconditioned SVRG
- 20th International Conference On Preconditioning, Minneapolis, MN, USA
Find the dimension that counts: Fast dimension estimation and Krylov PCA
- SIAM International Conference on Data Mining (SDM), Calgary, Canada
Error Correcting Codes for Machine Learning.
- CSA Seminar, Indian Institute of Science (IISc), Bengaluru, India

2018 *Error Correcting Codes for Machine Learning*
- Theory Seminar, University of Massachusetts, Amherst, MA
- IP Seminar, IBM T.J. Watson Research Center, NY

2017 *$UoI\text{-}NMF_{cluster}$: Robust Nonnegative Matrix Factorization Algorithm for Noisy Data*
- International Conference on Machine Learning and Applications (ICMLA), Cancun, Mexico
Multilabel Classification with Group Testing and Codes
- Neural Systems and Engineering Labs, Lawrence Berkeley National Laboratory, CA
- International Conference on Machine Learning (ICML), Sydney, Australia
Error Correcting Codes for Machine Learning
- The University of Melbourne, Melbourne, Australia
UoI-NMFcluster and UoI-CUR: Union of Intersections methods for matrix approximations
- Neural Systems and Engineering Labs, Lawrence Berkeley National Laboratory,CA

2016 *Error correcting codes for low rank approximation and group testing*
- BLISS Seminar, University of California, Berkeley, CA
Fast methods for estimating the Numerical rank of large matrices
- International Conference on Machine Learning (ICML), New York, NY

2015 *Low rank approximation using error correcting coding matrices*
- International Conference on Machine Learning (ICML), Lille, France

Awards

2023 ***Master Inventor Award***, IBM Research (3-year term)
2023 ***Outstanding Technical Achievement Award***, IBM Research
2022 *IBM Research Accomplishment Award*
2022 ***Outstanding Innovation Award***, IBM Research
2021 *IBM Research Accomplishment Award*
2019 *UMN Best Dissertation Award*, Computer Science Department nominee
2018 ***Herman Goldstine Fellowship***, IBM Research
2017 ***Best Paper Award***, International Conference on Machine Learning and Applications (ICMLA)
2011 *Visiting Research Student Program*, Raman Research Institute

Teaching

University of Texas, Austin, *Instructor*
Spring 2024 CSE 392, Topics in Computer Science: Matrix and Tensor Algorithms for Data

IBM Research, *Co-instructor*
Summer 2023 Mathematics of Big Data: Sketching and (Multi-) Linear Algebra, Organized at IBM, Almaden
Summer 2021 Mathematics of Big Data: Sketching and (Multi-) Linear Algebra at MSRI Berkeley

University of Minnesota, *Teaching Assistant*
Spring 2018 CSci 2033, Elementary Computational Linear Algebra, *Recitation Instructor*
Fall 2017 CSci 5304, Computational Aspects of Matrix Theory, *Teaching Assistant*
Spring 2017 CSci 8314, Sparse Matrix Computations, *Temporary Instructor*

Mentoring

IBM Research - Interns
2023 Arpan Mukerjee (PhD Student - RPI), jointly with K. Murugesan
2022 Elizabeth Yang (PhD Student - U of California, Berkeley), jointly with K. Clarkson
2021 Paz F. Sustin (PhD Student - Tel Aviv University), jointly with L. Horesh, H. Avron
2021 Lucky Yerimah (PhD Student - RPI), jointly with P. Ram
2021 Emily Thompson (REU Student via. DIMACS)
2020 Dong Hu (PhD Student - RPI), jointly with A. Gittens
2019 Osman Malik (PhD Student - U of Colorado, Boulder), jointly with L. Horesh

Services

Reviewer: National Science Foundation (NSF) grant proposals, 2023.
Conferences: Neural Information Processing Systems (NeurIPS) 2016, 2019- 22 ; International Conference on Machine Learning (ICML) 2018 - 23 ; International Conference on Learning Representations (ICLR) 2021-22; AAAI conference on Artificial Intelligence 2020 - 22 ; ACM-SIAM Symposium on Discrete Algorithms (SODA) 2021; Conference on Uncertainty in Artificial Intelligence (UAI) 2019 - 22; IEEE International Conference On Machine Learning And Applications 2018 - 19; IEEE International Symposium on Information Theory (ISIT) 2017.
Journals: Acta Materialia; PLOS One; Journal of Machine Learning Research; SIAM Journal on Matrix Analysis and Applications (3 articles); IEEE Transactions on Signal Processing; IEEE Transactions on Image Porcessing; Signal Processing Letters, IEEE Transactions on Information Theory; Electronic Transactions on Numerical Analysis (2 articles); IEEE Transactions on Signal and Information Processing over Networks; BIT Numerical Mathematics; Linear Algebra and Its Applications; Journal of Mathematics and Applications, Mathematical Modeling and Analysis; Journal of Imaging.

Organizer: SIAM MDS 2024 - Member of organizing committee.

SIAM CSE 2023 - Minisymposium on Randomized Algorithms for Matrix and Tensor Analysis

ICMLA Challenge 2018 - Parts based decomposition of noisy data.

MSRIT ROBONXG-2012 - a week long robotics festival.

Programming skills

Matlab, Python, C, C++, LATEX, Basic web programming.