

ZHIHUI ZHU

University of Denver
Department of Electrical and Computer Engineering
2155 East Wesley Avenue Denver, 126 C, CO 80208

Phone: 303-871-5249
Email: zhihui.zhu@du.edu
Web: cis.jhu.edu/~zhihui/

RESEARCH INTERESTS

- Machine learning, data science, signal processing, and computational engineering
- Design, analysis, and implementation of algorithms for high-dimensional and large-scale optimization problems
- Expressivity and generalization of deep neural network, and its application for inverse problems
- Signal and data processing using sparse, low-rank, and manifold-based models
- Approximation theory and computational harmonic analysis

EDUCATION

2017	Ph.D. in Electrical Engineering (Dr. Michael Wakin, advisor)	Colorado School of Mines
2012	B.E. in Telecommunications Engineering (Dr. Gang Li, advisor), winner of Best Bachelor's Thesis Award (1/125)	Zhejiang University of Technology Jianxing Honors College

POSITIONS

2020-	Assistant Professor	University of Denver Department of Electrical & Computer Engineering
2018-2019	Postdoctoral Fellow (Dr. René Vidal, advisor)	Johns Hopkins University Center for Imaging Science Mathematical Institute for Data Science
2014-2017	Research Assistant (Dr. Michael Wakin, advisor)	Colorado School of Mines Dept. of Electrical Engineering
2013-2014	Teaching Assistant	Colorado School of Mines Dept. of Electrical Engineering
2010-2013	Research Assistant (Dr. Gang Li, advisor)	Zhejiang University of Technology Zhejiang Key Lab. for Signal Processing

HONORS

2019	Finalist for the Best Student Paper Award	IEEE CAMSAP
2018	Electrical Engineering Graduate Research Award	Colorado School of Mines
2013	National Scholarship	Ministry of Education of PRC
2012	Best Bachelor's Thesis Award (1/125) for the Thesis "On The Sparse Representation of Signals in Compressive Sensing"	ZJUT

PREPRINTS¹

1. Q. Qu, Y. Zhai, X. Li, Y. Zhang, and Z. Zhu, "Analysis of the Optimization Landscapes for Overcomplete Representation Learning," arXiv preprint arXiv: 1912.02427, 2019.
2. X. Li, Z. Zhu, A. M. So, and J. Lee, "Incremental Methods for Weakly Convex Optimization," arXiv preprint arXiv:1907.11687, 2019.
3. Q. Qu, X. Li, and Z. Zhu, "A Nonconvex Approach for Exact and Efficient Multichannel Sparse Blind Deconvolution," arXiv preprint arXiv:1908.10776, 2019.
4. Z. Zhu, Y. Wang, D. P. Robinson, D. Naiman, R. Vidal, and M. C. Tsakiris, "Dual Principal Component Pursuit: Improved Analysis and Efficient Algorithms," arXiv preprint arXiv:1812.09924, 2019.
5. Q. Li*, Z. Zhu*, G. Tang, and M. B. Wakin, "Provable Bregman-divergence based Methods for Nonconvex and Non-Lipschitz Problems," arXiv preprint arXiv:1904.09712, 2019.
6. Z. Zhu and X. Li, "Convergence Analysis of Alternating Nonconvex Projections," arXiv preprint arXiv:1802.03889, 2018.
7. Z. Zhu and M. B. Wakin, "Time-Limited Toeplitz Operators on Abelian Groups: Applications in Information Theory and Subspace Approximation," arXiv preprint arXiv:1711.07956, 2017.
8. Z. Zhu, Q. Li, G. Tang, and M. B. Wakin, "The Global Optimization Geometry of Low-Rank Matrix Optimization," arXiv preprint arXiv:1703.01256, 2017.

JOURNAL PUBLICATIONS

1. X. Li*, Z. Zhu*, A.M.-C. So, and R. Vidal, "Nonconvex Robust Low-rank Matrix Recovery," to appear in *SIAM Journal on Optimization*, 2020.
2. Z. Zhu, D. Soudry, Y. C. Eldar, and M. B. Wakin, "The Global Optimization Geometry of Shallow Linear Neural Networks," to appear in *Mathematical Foundations of Deep Learning in Imaging Science*, special issue of *Journal of Mathematical Imaging and Vision*, 2019.
3. Q. Li, Z. Zhu, and G. Tang, "The Non-convex Geometry of Low-rank Matrix Optimization," *Information and Inference: A Journal of the IMA*, vol 8, no. 1, pp. 51-96, March 2019.
4. S. Karnik, Z. Zhu, M. B. Wakin, J. Romberg, and M. A. Davenport, "The Fast Slepian Transform," *Applied and Computational Harmonic Analysis*, vol 46, no. 3, pp. 624-652, May 2019.
5. T. Hong, X. Li, Z. Zhu, and Q. Li, "Optimized Structured Sparse Sensing Matrices for Compressive Sensing," *Signal Processing*, vol. 159, pp. 119-129, June 2019.
6. C. Wang, Z. Zhu, H. Gu, X. Wu, and S. Liu, "Hankel Low-Rank Approximation for Seismic Noise Attenuation," *IEEE Transactions on Geoscience and Remote Sensing*, vol 57, no. 1, pp. 561-573, January 2019.
7. Z. Zhu, S. Karnik, M. Wakin, M. Davenport, and J. Romberg, "ROAST: Rapid Orthogonal Approximate Slepian Transform," *IEEE Transactions on Signal Processing*, vol 66, no. 22, pp. 5887-5901, November 2018.

¹*indicates equal contribution.

8. Z. Zhu, G. Li, J. Ding, Q. Li, and X. He, “On Collaborative Compressive Sensing Systems: The Framework, Design and Algorithm,” *SIAM Journal on Imaging Sciences*, vol. 11, no. 2, pp. 1717-1758, 2018.
9. Z. Zhu, Q. Li, G. Tang, and M. B. Wakin, “Global Optimality in Low-rank Matrix Optimization,” *IEEE Transactions on Signal Processing*, vol. 66, no. 13, pp. 3614-3628, July 2018.
10. T. Hong and Z. Zhu, “An Efficient Method for Robust Projection Matrix Design,” *Signal Processing*, vol. 143, pp. 200-210, February 2018.
11. Z. Zhu, S. Karnik, M. A. Davenport, J. K. Romberg, and M. B. Wakin, “The Eigenvalue Distribution of Discrete Periodic Time-Frequency Limiting Operators,” *IEEE Signal Processing Letters*, vol. 25, no. 1, pp. 95–99, January 2018.
12. Z. Zhu and M. B. Wakin, “Approximating Sampled Sinusoids and Multiband Signals Using Multiband Modulated DPSS Dictionaries,” *Journal of Fourier Analysis and Applications*, vol. 23, no. 6, pp. 1263–1310, December 2017.
13. X. Wu, and Z. Zhu, “Methods to Enhance Seismic Faults and Construct Fault Surfaces,” *Computers & Geosciences*, vol. 107, pp. 37-48, October 2017.
14. Z. Zhu and M. B. Wakin, “On the Asymptotic Equivalence of Circulant and Toeplitz Matrices,” *IEEE Transactions on Information Theory*, vol. 63, no. 5, pp. 2975-2992, May 2017.
15. S. Liu, M. Liu, P. Li, J. Zhao, Z. Zhu, and X. Wang, “SAR Image Denoising via Sparse Representation in Shearlet Domain Based on Continuous Cycle Spinning,” *IEEE Transactions on Geoscience and Remote Sensing*, vol. 55, no. 5, pp. 2985-2992, 2017.
16. H. Tao, H. Bai, S. Li, and Z. Zhu, “An Efficient Algorithm for Designing Projection Matrix in Compressive Sensing Based On Alternating Optimization,” *Signal Processing*, vol. 125, pp. 9-20, 2016.
17. G. Li, Z. Zhu, D. Yang, L. Chang, and H. Bai, “On Projection Matrix Optimization for Compressive Sensing Systems,” *IEEE Transactions on Signal Processing*, vol. 61, no. 11, pp. 2887-2898, June 2013.

CONFERENCE PUBLICATIONS—MACHINE LEARNING

1. Q. Qu, Y. Zhai, X. Li, Y. Zhang, and Z. Zhu, “Analysis of the Optimization Landscapes for Overcomplete Representation Learning,” to appear in *International Conference on Learning Representations (ICLR)*, Addis Ababa, Ethiopia, April 2020. (oral, top 1.85%)
2. Z. Zhu, T. Ding, M.C. Tsakiris, D. Robinson, and R. Vidal, “A Linearly Convergent Method for Non-smooth Non-convex Optimization on Grassmannian with Applications to Robust Subspace and Dictionary Learning,” *Neural Information Processing Systems (NeurIPS)*, Vancouver, Canada, December 2019. (acceptance rate = 21%)
3. Z. Zhu, Q. Li, X. Yang, G. Tang, and M. B. Wakin, “Global Optimality in Distributed Low-rank Matrix Factorization,” *Neural Information Processing Systems (NeurIPS)*, Vancouver, Canada, December 2019. (acceptance rate = 21%)
4. Q. Qu, X. Li, and Z. Zhu, “A Nonconvex Approach for Exact and Efficient Multichannel Sparse Blind Deconvolution,” to appear in *Neural Information Processing Systems (NeurIPS)*, Vancouver, Canada, December 2019. (spotlights, acceptance rate = 200/6743)
5. Q. Li*, Z. Zhu*, and G. Tang, “Alternating Minimizations Converge to Second-Order Optimality Solutions”, *International Conference on Machine Learning (ICML)*, Long Beach, CA, USA, June 2019. (acceptance rate = 22%)

6. T. Ding*, Z. Zhu*, T. Ding, M. C. Tsakiris, D. P. Robinson, and R. Vidal, “Noisy Dual Principal Component Pursuit”, *International Conference on Machine Learning (ICML)*, Long Beach, CA, USA, June 2019. (acceptance rate = 22%)
7. Z. Zhu, Y. Wang, D. P. Robinson, D. Naiman, R. Vidal, and M. C. Tsakiris, “Dual Principal Component Pursuit: Improved Analysis and Efficient Algorithms,” *Neural Information Processing Systems (NIPS)*, December 2018. (acceptance rate = 20.8%)
8. Z. Zhu*, X. Li*, K. Liu, and Q. Li, “Dropping Symmetry for Fast Symmetric Nonnegative Matrix Factorization,” *Neural Information Processing Systems (NIPS)*, December 2018. (acceptance rate = 20.8%)

CONFERENCE PUBLICATIONS—SIGNAL PROCESSING

1. Q. Li, X. Yang, Z. Zhu, G. Tang, and M. B. Wakin, “The Geometric Effects of Distributing Constrained Nonconvex Optimization Problems,” *IEEE International Workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP)*, 2019. (candidates for the Best Student Paper Award)
2. Y. Li, Y. Zhang, and Zhihui Zhu, “Learning Deep Networks under Noisy Labels for Remote Sensing Image Scene Classification,” *IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Yokohama, Japan, July 2019.
3. Q. Li, Z. Zhu, G. Tang, and M. B. Wakin, “The Geometry Of Equality-Constrained Global Consensus Problems,” *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, Brighton, UK, May 2019.
4. Z. Zhu, M. Lopez-Santillana, and M. B. Wakin, “Super-Resolution of Complex Exponentials from Modulations with Known Waveforms,” *IEEE International Workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP)*, Curacao, Dutch Antilles, December 2017.
5. Z. Zhu, Q. Li, G. Tang, and M. B. Wakin, “Global Optimality in Low-rank Matrix Optimization,” *IEEE Global Conference on Signal and Information Processing (GlobalSIP)*, Montreal, Quebec, Canada, November 2017.
6. Z. Zhu, D. Yang, M. B. Wakin, and G. Tang, “A Super-Resolution Algorithm for Multiband Signal Identification,” *51st Asilomar Conference on Signals, Systems and Computers*, Pacific Grove, California, October 2017.
7. Z. Zhu, S. Karnik, M. B. Wakin, M. A. Davenport, and J. K. Romberg, “Fast Orthogonal Approximations of Sampled Sinusoids and Bandlimited Signals,” *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, New Orleans, March 2017.
8. G. Li, Z. Zhu, H. Bai, and A. Yu, “A New Framework for Designing Incoherent Sparsifying Dictionaries,” *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, New Orleans, March 2017.
9. Q. Li, S. Li, H. Mansour, M. Wakin, D. Yang, and Z. Zhu, “JAZZ: A Companion to MUSIC for Frequency Estimation with Missing Data,” *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, New Orleans, March 2017.
10. S. Karnik, Z. Zhu, M. B. Wakin, J. K. Romberg, and M. A. Davenport, “Fast Computations for Approximation and Compression in Slepian Spaces,” *IEEE Global Conference on Signal and Information Processing (GlobalSIP)*, Greater Washington, D.C., December 2016.

11. Z. Zhu and M. B. Wakin, "On the Dimensionality of Wall and Target Return Subspaces in Through-the-Wall Radar Imaging," *4th International Workshop on Compressed Sensing Theory and its Applications to Radar, Sonar and Remote Sensing (CoSeRa)*, Aachen, Germany, September 2016.
12. Z. Zhu, G. Tang, P. Setlur, S. Gogineni, M. Wakin, and M. Rangaswamy, "Super-Resolution in SAR Imaging: Analysis With the Atomic Norm," *IEEE Sensor Array and Multichannel Signal Processing (SAM) Workshop*, Rio de Janeiro, Brazil, July 2016.
13. Z. Zhu and M. B. Wakin, "New Analysis of Multiband Modulated DPSS Dictionaries," *Workshop on Signal Processing with Adaptive Sparse Structured Representations (SPARS)*, Cambridge, England, July 2015.
14. Z. Zhu and M. B. Wakin, "Wall Clutter Mitigation and Target Detection Using Discrete Prolate Spheroidal Sequences," *3rd International Workshop on Compressed Sensing Theory and its Applications to Radar, Sonar and Remote Sensing (CoSeRa)*, Pisa, Italy, June 2015.
15. Z. Zhu and M. B. Wakin, "Detection of Stationary Targets Using Discrete Prolate Spheroidal Sequences," *International Review of Progress in Applied Computational Electromagnetics (ACES)*, Williamsburg, Virginia, March 2015.
16. H. Bai, Z. Zhu, G. Li, and S. Li, "Design of Optimal Measurement Matrix for Compressive Detection," *International Symposium on Wireless Communication Systems (ISWCS)*, Ilmenau, Germany, August 2013.
17. S. Li, Z. Zhu, G. Li, L. Chang, and Q. Li, "Projection Matrix Optimization for Block-sparse Compressive Sensing," *IEEE International Conference on Signal Processing, Communication and Computing (ICSPCC)*, KunMing, August 2013.
18. Q. Li, Z. Zhu, S. Tang, L. Chang, and G. Li, "Projection Matrix Optimization Based on SVD for Compressive Sensing Systems," *Chinese Control Conference (CCC)*, July 2013.
19. Z. Zhu, D. Yang, G. Li, and C. Huang, "Stable 2nd Order Adaptive IIR filter Structure for Blind Deconvolution," *International Congress on Image and Signal Processing (CISP)*, Shanghai, October 2011.

TUTORIALS

1. "Nonconvex Approaches for Data Science," *School of Information Science and Technology, ShanghaiTech University*, June 2019.

INVITED PRESENTATIONS

1. "Provable Nonsmooth Nonconvex Approaches for Low-Dimensional Models", *Statistics, Optimization and Machine Learning (StaOptML) Seminar*, University of Colorado Boulder, Jan 2020.
2. "Provable Nonsmooth Nonconvex Approaches for Low-Dimensional Models", *Signal and Information Processing Seminar (SIP) Seminar*, Rutgers University, Dec 2019.
3. "Provable Nonconvex Approaches for Low-rank Models", *Workshop on Low-Rank Models and Applications (LRMA)*, University of Mons, Belgium, Sep 2019.
4. "A Linearly Convergent Method for Non-Smooth Non-Convex Optimization on the Sphere with Applications to Robust Subspace and Dictionary Learning", *the Sixth International Conference on Continuous Optimization (ICCOPT)*, Technical University (TU) of Berlin, Aug 2019.
5. "Nonconvex Approaches for Data Science," *Wuhan University*, June 2019.

6. “Nonconvex Approaches for Data Science,” *Zhejiang University of Technology*, June 2019.
7. “Nonconvex Nonsmooth Approaches for Data Science,” *Center for Data Science*, New York University, April 2019.
8. “Nonconvex Approaches for Data Science,” *University of Denver*, Feb 2019.
9. “Nonconvex Approaches for Data Science,” *George Washington University*, Feb 2019.
10. “Nonconvex Approaches for Data Science,” *University of Utah*, March 2019.
11. “Nonconvex Approaches for Data Science,” *University of Vermont*, March 2019.
12. “Nonconvex Approaches for Data Science,” *University of North Texas*, March 2019.
13. “Nonconvex Approaches for Data Science,” *University of Hawaii at Manoa*, March 2019.
14. “Nonconvex Geometry of Low-rank Matrix Optimizations,” *JHU Vision Lab*, 2017.
15. “A Super-resolution Algorithm for Multiband Signal Identification,” *51st Asilomar Conference on Signals, Systems and Computers*, Pacific Grove, October 2017.

POSTERS and CONTRIBUTED PRESENTATIONS

1. “A Linearly Convergent Method for Non-smooth Non-convex Optimization on Grassmannian with Applications to Robust Subspace and Dictionary Learning,” *Computational Imaging Workshop, Institute for Mathematics and its Applications, University of Minnesota Twin Cities*, October 2019.
2. “Fast Orthogonal Approximations of Sampled Sinusoids and Bandlimited Signals,” *Graduate Research And Discovery Symposium (GRADS), Colorado School of Mines*, April 2017.
3. “Fast Orthogonal Approximations of Sampled Sinusoids and Bandlimited Signals,” *Computing-Mines Affiliates Partnership Program (C-MAPP) Award Event*, January 2017.
4. “Wall Clutter Mitigation and Target Detection in Through-the-Wall Radar Imaging,” *Graduate Research And Discovery Symposium (GRADS), Colorado School of Mines*, March 2016.
5. “On the Asymptotic Equivalence of Circulant and Toeplitz Matrices”, *2016 February Fourier Talks – FFT 2016, Norbert Wiener Center for Harmonic Analysis and Applications, Department of Mathematics, University of Maryland*, College Park, Maryland, February 2016.
6. “SAR Radar Imaging of Targets Through the Wall,” *Graduate Research And Discovery Symposium (GRADS), Colorado School of Mines*, January 2016.
7. “New Analysis of Multiband Modulated DPSS Dictionaries,” *Zhejiang Key Laboratory for Signal Processing*, May 2015.
8. “SAR Radar Imaging of Targets Through the Wall”, *Graduate Research And Discovery Symposium (GRADS), Colorado School of Mines*, April 2015.

TEACHING EXPERIENCE

May 2018	Johns Hopkins Teaching Institute offered by Johns Hopkins Teaching Academy
Sep. 2016	Substitute Lecturer for <i>Information Systems Science II</i> (EENG 311)
2013-2014	Lab Instructor for <i>Digital Logic</i> (EENG 284)
Fall 2012	Teaching Assistant for <i>Signals and Systems</i>

PROFESSIONAL ACTIVITIES

Professional Societies

IEEE, SIAM

Technical Program Committees

IEEE International Conference on Digital Signal Processing (DSP), 2017

IEEE International Conference on Communication Technology (ICCT), 2017 & 2018

Reviewer for the Following Journals

Applied Computational and Harmonic Analysis

Birkhauser Springer Series on Harmonic Analysis

Digital Signal Processing

Frontiers in Applied Mathematics and Statistics

IEEE Geoscience and Remote Sensing Letters

IEEE Journal of Selected Topics in Signal Processing

IEEE Signal Processing Letters

IEEE Transactions on Information Theory

IEEE Transactions on Signal Processing

Information and Inference: A Journal of the IMA

International Journal of Computer Vision

Pattern Recognition Letters

Signal Processing

Reviewer for the Following Conferences

IEEE Radar Conference (RadarConf)

IEEE Int. Conference on Digital Signal Processing (DSP)

IEEE Int. Workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP)

International Conference on Learning Representations (ICLR)

Neural Information Processing Systems (NIPS)

EDUCATION EXPERIENCE

We presented lessons and activities related to signal filtering, movie recommendation systems, Google PageRank, and signal and video enhancement at the Mines Tech Camp/Discover STEM summer outreach program for middle school students (2014-2016), the Creating Technology program for high school girls (2015), and the Rocky Mountain Camp summer camp for dyslexic kids (2015-2016).

SERVICES

2010-2012 President of Mathematical Modeling Association, ZJUT

2011-2012 Counselor Assistant, Jianxing Honors College, ZJUT

2010-2012 Class Monitor, ZJUT