Reinhard Heckel

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Adjunct Assistant Professor, Rice University
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Research interests

Machine learning, signal and information processing, optimization, and statistics.

Current focus is on i) developing algorithms and theory for deep learning, in particular for solving signal and image reconstruction problems with deep learning, ii) learning from few and noisy examples, and iii) DNA data storage and DNA as digital information technology.

Education

08/2010 - 10/2014 **ETH Zurich**, Zurich, Switzerland.
Ph.D. in Electrical Engineering, **ETH medal for outstanding thesis**
- Advisor: Prof. Helmut Bölcskei

09/2013 - 12/2013 **Stanford University**, Stanford, CA, United States.
Visiting Ph.D. Student with Prof. Emmanuel Candès

10/2005 - 05/2010 **University of Ulm**, Ulm, Germany.
Diploma (equiv. M.S. degree) in Electrical Engineering, **with Honors**.

Awards

- Runner up (second place) in the 2021 AAPM (American Association of Physicists in Medicine) Grand Challenge: "Deep Learning for Inverse Problems: Sparse-View Computed Tomography Image Reconstruction"
- Featured in the BBC Future series "The Genius Behind": This is how to store human knowledge for eternity, 2015
- ETH Zurich medal for outstanding Ph.D. thesis, 2015
- IBM first patent application invention achievement award, 2015
- Early Postdoc.Mobility fellowship from the Swiss National Science Foundation, 2014
- Best student paper award at the Int. Workshop on Comp. Systems Biology, 2012

Academic experience

06/2019 - present **Technical University of Munich**, Munich, Germany.
Assistant Professor at the Department of Electrical and Computer Engineering
Rudolf Mössbauer Tenure Track Professor, TUM Institute of Advanced Studies

06/2019 - present **Rice University**, Houston, TX.
Adjunct Assistant Professor at the Department of Electrical and Computer Engineering

08/2017 - 05/2019 **Rice University**, Houston, TX.
Assistant Professor at the Department of Electrical and Computer Engineering

01/2016 - 07/2017 **University of California Berkeley**, Berkeley, CA.
Postdoc at the Department of Electrical Engineering and Computer Sciences

12/2014 - 12/2015 **IBM Research**, Zurich, Switzerland.
Researcher at the Department of Cognitive Computing & Computational Sciences

08/2010 - 11/2014 **ETH Zurich**, Zurich, Switzerland.
Research and teaching assistant at the Communication Technology Laboratory

Teaching

At TUM

- Summer 2021: Deep learning for inverse problems
- Winter 2019 and 2020: Optimization and machine learning
- Winter 2020: Seminar on the foundations and robustness of deep learning
- Summer 2019, 2020, and 2021: Introduction to machine learning
- Summer 2020: Seminar on the foundation of deep learning in imaging science

At Rice

- Fall 2017, Spring 2019: ELEC 577 Optimization for data science
- Fall 2018: ELEC 578 Introduction to machine learning
- Spring 2018: ELEC 631 Deep networks for inference and estimation, jointly taught with Richard Baraniuk

Funding

Total external funding awarded as an assistant professor: $1,997,400

- DFG project "Solving linear inverse problems with end-to-end neural networks: expressivity, generalization, and robustness", recommended for funding 2021 as co PI; Individual part: 209.400 Euro ($249.523)
- DFG project "Theory of un-trained neural networks for image recovery", awarded 2021 as single PI. 294,000 Euro ($356,628).
- "6G Future Lab Bavaria", awarded 2021 as co-PI. Individual part ca. 210,000 Euro ($252,305).
- EU project "DNA-Fast light dRiven data technologY with multiplexed optical encoding and readout", awarded 2020 as co-PI. Individual part: 324,780 Euro ($388,558).
- NIH "Polycyclic aromatic hydrocarbons: Ultrasensitive detection, early life exposures-clinical outcomes (preterm births, chronic lung disease, and neurocognitive deficits), prevention, and remediation", awarded 2019 as co-PI. Individual part: $276,064.
- NSF IIS Small "Actively learning from the crowd", awarded 2018 as a single PI: $474,322.

Mentoring and student supervision

Current group

- Mohammad Zalbagi Darestani, 3rd year PhD student at Rice
- Zhenwai Dai, 3rd year PhD student at Rice, co-advised with Anshumali Shrivastava
- Tobit Klug, 1st year PhD student at TUM

- Jiayu Liu, 1st year PhD student at TUM (starting June 2021)
- Fatih Furkan Yilmaz, 4rd year PhD student at Rice

Master student supervision at TUM

Lena Heidemann, Tobit Klug, Zi Yang, Yundi Zhang, Frederik Fraaz, Benedikt Böck, Kang Lin, Youssef Mansour

Undergraduate supervision at TUM

Jacob Geussen, Oleksii Khakhlyuk, Mohammed Amine Ketata, Amal Trigui

Master thesis supervision at ETH

Cécile Chenot, Celestine Dünner, Irene Pappalardo, Michael Tschannen

Service

Organization of workshops/conferences

- Co-chair of the NeurIPS 2021 workshop "Deep Learning and Inverse Problems"
- Co-chair of the NeurIPS 2020 workshop "Deep Learning and Inverse Problems"
- Technical Area Chair for Adaptive Systems, Machine Learning, Data Analytics at the 2019 Asilomar conference
- Co-chair of the NeurIPS 2019 workshop "Solving inverse problems with deep networks: New architectures, theoretical foundations, and applications"

Departmental service at Rice University

- Founded, acquired $20.000 funding for, and co-running (with students from ECE, CS, and Stats) a weekly machine learning lunch series that averages more than 70 participants per week
- Member of the graduate committee
- Member of the ECE search committee for the faculty search in "Embedded Machine Learning"

Member in PhD and Master committees

- Jangwon Kim, PhD in Bioengineering, Rice University, 2020
- Souptik Barua, PhD in ECE, Rice University, 2019
- Babhru Joshi, PhD in Applied Mathematics, Rice University, 2019
- Chris Metzler, PhD in ECE, Rice University, 2018
- CJ Barberan, Masters in ECE, Rice University, 2019
- Oscar Leong, Master in Applied Mathematics, Rice University, 2018
- Akash Kumar Maity, Masters in ECE Rice University, 2018
- Qiang Zhang, Masters in Applied Mathematics, Rice University, 2018

Publications

5 representative papers marked with *

Long papers in highly selective conferences

*L1 M. Zalbagi Darestani, A. Chaudhari, and **R. Heckel**
Measuring Robustness in Deep Learning Based Compressive Sensing
ICML 2021 (**long talk**, top 3% of submissions).

L2 Z. Fabian, **R. Heckel**, and M. Soltanolkotabi
Data augmentation for deep learning based accelerated MRI reconstruction with limited data
ICML 2021.

L3 **R. Heckel** and F. F. Yilmaz
Early stopping in deep networks: Double descent and how to eliminate it
ICLR 2021

L4 Z. Dai, A. Desai, **R. Heckel**, A. Shrivastava
Active Sampling Count Sketch (ASCS) for Online Sparse Estimation of a Trillion Scale Covariance Matrix
SIGMOD 2021

L5 **R. Heckel** and M. Soltanolkotabi
Compressive sensing with un-trained neural networks: Gradient descent finds the smoothest approximation
ICML 2020

*L6 **R. Heckel** and M. Soltanolkotabi
Denoising and regularization via exploiting the structural bias of convolutional generators
ICLR 2020

*L7 **R. Heckel** and P. Hand
Deep decoder: Concise image representations from untrained non-convolutional networks
ICLR 2019

L8 D. LeJeune, R. Baraniuk, and **R. Heckel**
Adaptive estimation for approximate k-nearest-neighbor computations
AISTATS 2019

L9 **R. Heckel**, M. Simchowitz, K. Ramchandran, and M. Wainwright
Approximate ranking from pairwise comparisons
AISTATS 2018

L10 **R. Heckel** and K. Ramchandran
The sample complexity of online one-class collaborative filtering
ICML 2017

L11 **R. Heckel**, M. Vlachos, T. Parnell, and C. Dünner
Scalable and interpretable product recommendations via overlapping co-clustering
ICDE 2017

L12 **R. Heckel** and M. Vlachos, "Private and right-protected big data publication: An analysis
SIAM Data Mining 2017

Journal articles

J1 M. Zalbagi Darestani and **R. Heckel**
Accelerated MRI with Un-trained Neural Networks
IEEE Transactions on Computational Imaging, 2021.

J2 W. Huang, **R. Heckel**, P. Hand, V. Voroninski,
A provably convergent scheme for compressive sensing under random generative priors
Journal of Fourier Analysis and Applications, 2021.

J3 I. Shomorony and **R. Heckel**
DNA-Based Storage: Models and Fundamental Limits
IEEE Trans. Inf. Theory, 2021.

* J4 P. L. Antkowiak, J. Lietard, M. Zalbagi Darestani, M. Somoza, W. J. Stark, **R. Heckel***, R. N. Grass*
Low cost DNA data storage using photolithographic synthesis and advanced information reconstruction and error correction
Nature Communications, 2020 (*=corresponding authors), **featured as Editor's highlight**.

J5 L. C. Meiser, J. Koch, P. L. Antkowiak, W. J. Stark, **R. Heckel**, R. N. Grass
DNA synthesis for true random number generation
Nature Communications, 2020.

J6 **R. Heckel**, W. Huang, P. Hand, V. Voroninski,
Deep denoising: Rate-optimal recovery of structured signals with a deep prior
Information and Inference: A Journal of the IMA, 2020.

J7 E. Bostan, **R. Heckel**, M. Chen, M. Kellman, L. Waller
Deep Phase Decoder: Self-calibrating phase microscopy with an untrained deep neural network
Optica, 2020.

J8 R. Grass, **R. Heckel**, C. Dessimoz, W. J. Stark,
Genomic encryption of digital data stored in synthetic DNA
Angewandte Chemie International Edition, 2020.

J9 L. Meiser, P. Antkowiak, J. Koch, W. Chen, A. X. Kohll, W. J. Stark, **R. Heckel***
R. N. Grass* (*=corresponding authors)
Reading and writing digital data in DNA
Nature Protocols, 2019, **featured on the cover of the January 2020 issue**.

J10 **R. Heckel**, G. Mikutis, and R. N. Grass
A Characterization of the DNA Data Storage Channel
Scientific Reports, 2019.

J11 W. Chen, A. Kohll, B. Nguyen, J. Koch, **R. Heckel**, W. J. Stark, L. Ceze, K. Strauss, R. N. Grass
Combining data longevity with high storage capacity–layer-by-layer DNA encapsulated

in magnetic nanoparticles
Advanced Functional Materials, 2019.

*J12 **R. Heckel**, N. B. Shah, K. Ramchandran, and M. J. Wainwright
Active ranking from pairwise comparisons and when parametric assumptions don't help
Annals of Statistics, 2019.

J13 **R. Heckel**
An archive written in DNA
Nature Biotechnology, 2018.

J14 M. Vlachos, C. Duenner, **R. Heckel**, V.G. Vassiliadis, T. Parnell, K. Atasu
Addressing interpretability and cold-start in matrix factorization for recommender systems
IEEE Trans. on Knowl. and Data Eng., 2018.

J15 N. Antipa, G. Kuo, **R. Heckel**, B. Mildenhall, E. Bostan, R. Ng, L. Waller
DiffuserCam: Lensless single-exposure 3D imaging
Optica, 2018.

J16 **R. Heckel** and M. Soltanolkotabi
Generalized line spectral estimation via convex optimization
IEEE Trans. Inf. Theory, 2018.

J17 **R. Heckel**, M. Tschannen, and H. Bölcskei
Dimensionality-reduced subspace clustering
Information and Inference: A Journal of the IMA, 2017.

J18 M. Vlachos, V.G. Vassiliadis, **R. Heckel**, A. Labbi
Toward interpretable predictive models in B2B recommender systems
IBM Journal of Research and Development, 2016.

J19 **R. Heckel**, V. I. Morgenshtern, M. Soltanolkotabi
Super-resolution radar
Information and Inference: A Journal of the IMA, 2016.

J20 **R. Heckel** and H. Bölcskei
Robust subspace clustering via thresholding
IEEE Trans. Inf. Theory, 2015.

J21 D. Paunescu, C. A. Mora, L. Querci, **R. Heckel**, M. Puddu, B. Hattendorf, D. Günther, and R. N. Grass
Detecting and number counting of single engineered nanoparticles by digital particle polymerase chain reaction
ACS Nano, 2015, **selected by ACS as Editors Choice**.

J22 R. Grass, **R. Heckel**, M. Puddu, D. Paunescu, and W. J. Stark
Robust chemical preservation of digital information on DNA in silica with error-correcting codes
Angewandte Chemie International Edition, 2015, **featured in Nature as research highlight, press coverage by BBC, CNN, and IEEE Spectrum**.

J23 **R. Heckel** and H. Bölcskei
Identification of sparse linear operators
IEEE Trans. Inf. Theory, 2013.

J24 **R. Heckel**, S. Schober, and M. Bossert
Harmonic analysis of Boolean networks: Determinative power and perturbations
EURASIP J. Bioinform. Syst. Biol., 2013.

J25 J. Klotz, **R. Heckel**, and S. Schober,
Bounds on the average sensitivity of nested canalizing functions
PLoS ONE, 2013.

J26 S. Schober, D. Kracht, **R. Heckel**, and M. Bossert
Detecting controlling nodes of Boolean regulatory networks
EURASIP J. Bioinform. Syst. Biol., 2011.

Refereed conference proceedings

C1 M. Zalbagi Darestani and **R. Heckel**
Can Un-trained Networks Compete with Trained Ones for Accelerated MRI?
ISMRM, oral presentation, 2021.

C2 D. Van Veen, A. Desai, **R. Heckel**, A. Chaudhari
Using Untrained Convolutional Neural Networks to Accelerate MRI in 2D and 3D
ISMRM, 2021.

C3 S. Shin, **R. Heckel**, I. Shomorony "Capacity of the Erasure Shuffling Channel",
ICASSP, 2020.

C4 **R. Heckel** "Signal recovery with un-trained convolutional neural networks",
NeurIPS medical imaging workshop, 2019.

C5 Z. Dai and **R. Heckel** "Channel Normalization in Convolutional Neural Network avoids Vanishing Gradients",
ICML Deep Phenomena Workshop, 2019

C6 I. Shomorony and **R. Heckel** "Capacity Results for the Noisy Shuffling Channel",
ISIT, 2019

C7 F. Ong, **R. Heckel**, K. Ramchandran "A fast and robust paradigm for Fourier compressed sensing based on coded sampling"
ICASSP, 2019

C8 C. Metzler, A. Mousavi, **R. Heckel**, R. Baraniuk "Unsupervised Learning with Stein's Unbiased Risk Estimator",
International Biomedical and Astronomical Signal Processing (BASP) Frontiers workshop, 2019, **best contribution award**.

C9 **R. Heckel***, I. Shomorony*, K. Ramchandran, and D. Tse "Fundamental Limits of DNA Storage Systems,"
ISIT, 2017 (* equal contribution).

C10 **R. Heckel** and M. Soltanolkotabi, "Generalized Line Spectral Estimation for Radar and Localization,"
CoSeRa, 2016, **invited paper**.

C11 **R. Heckel**, "Super-resolution MIMO radar,"
ISIT, 2016.

C12 **R. Heckel**, M. Tschannen, and H. Bölcskei, "Subspace clustering of dimensionality reduced data,"
ISIT, 2014.

C13 A. Jung, **R. Heckel**, H. Bölcskei, and F. Hlawatsch, "Compressive nonparametric graphical model selection for time series,"
ICASSP, 2014.

C14 **R. Heckel**, E. Agustsson, and H. Bölcskei, "Neighborhood selection for thresholding based subspace clustering,"
ICASSP, 2014.

C15 **R. Heckel** and H. Bölcskei, "Noisy subspace clustering via thresholding,"
ISIT, 2013.

C16 **R. Heckel** and H. Bölcskei, "Subspace clustering via thresholding and spectral clustering,"
ICASSP, 2013.

C17 **R. Heckel** and H. Bölcskei, "Joint sparsity with different measurement matrices,"
Allerton, 2012, **invited paper**.

C18 **R. Heckel**, S. Schober, and M. Bossert, "Determinative power and tolerance to perturbations in Boolean networks,"
WCSB, 2012, **best student paper award**.

C19 **R. Heckel** and H. Bölcskei, "Compressive identification of linear operators,"
ISIT, 2011.

C20 S. Schober, **R. Heckel**, and D. Kracht, "Spectral properties of a Boolean model of the E. coli genetic network and its implication on network inference,"
WCSB, 2010.

C21 **R. Heckel**, S. Schober, and M. Bossert, "On random Boolean threshold networks,"
SCC, 2010.

C22 **R. Heckel** and S. Schober, "A Boolean genetic regulatory network created by whole genome duplication,"
WCSB, 2009.

Patents

P1 **R. Heckel**, V. Vasileiadis, and M. Vlachos, "Method and system for identifying dependent components", US Patent 20,160,063,392, 2016.

P2 **R. Heckel** and M. Vlachos, "The obfuscation and protection of data rights", US Patent 9,916,472, 2015.

Book Chapters

B1 **R. Heckel**, "Super-resolution radar imaging via convex optimization", Chapter "Compressed Sensing based Radar Signal Processing", 2019.

Recent invited talks

2021 "Measuring Robustness in Deep Learning Based Compressive Sensing", Machine Learning for Algorithms Workshop of the Foundations of Data Science Institute (FODSI)

"Low cost DNA data storage with noisy synthesis and advanced error correction", JPEG DNA Workshop

2020 "Tutorial on Deep networks for inverse problems", IEEE European School of Information Theory

"Image recovery with untrained convolutional neural networks", Stanford SCIEN Colloquium

"Provable Image Recovery with Untrained Convolutional Neural Networks", One World Mathematics of Information, Data, and Signals Seminar.

"Image recovery and recognition via exploiting the structural bias of neural networks", Math FLDS / CPS seminar, University of Southern California (USC)

2019 "Denoising and regularization via exploiting the structural bias of convolutional generators", Berkeley, Computational Imaging Lunch

"Denoising and regularization via exploiting the structural bias of convolutional generators", Stanford, Information Systems Lab Colloquium

"Image recovery and restoration with neural networks and robust storage of information on DNA", ETH, Institute for Chemical and Bioengineering Seminar

"Denoising and regularization with untrained neural networks", Asilomar Conference on Signals, Systems, and Computers

"Denoising and regularization via exploiting the structural bias of convolutional generators", Allerton Conference on Communication, Control, and Computing

"Deep Decoder: Concise image representations from untrained networks", Math+X symposium on inverse problems and deep learning in space exploration

"Regularizing inverse problems with untrained neural networks", Machine Learning in Solid Earth Geoscience Workshop, Los Alamos

"Deep Decoder: Concise image representations from untrained networks", Information Theory and Applications Workshop, San Diego

"Deep Decoder: Concise image representations from untrained networks", University of Washington, Machine learning seminar

2018 "Deep Decoder: Concise image representations from untrained networks", UIUC, Coordinate Science Lab, SINE Seminar

"Deep Decoder: Concise image representations from untrained networks", Winedale workshop, Windedale, Texas

"Deep Decoder: Concise image representations from untrained networks", Rice University, CAAM colloquium

"Robust storage of information in DNA molecules", Microsoft Research Redmond

"Robust storage of information in DNA molecules", EPFL, IC talk

"Robust storage of information in DNA molecules", Berkeley, Berkeley Laboratory for Information and System Sciences (BLISS) Seminar

"Approximate ranking from pairwise comparisons", Information Theory and Applications Workshop

2017 "Robust preservation of digital information on DNA with error-correcting codes", UT Austin, DNA23 conference

"Robustness and complexity tradeoffs in inference and learning", Rice University

"Robustness and complexity tradeoffs in inference and learning", Cornell

"Collection and preserving information efficiently and reliably", Cornell Tech

"Algorithms and theory for efficient data collection, information extraction, and preservation", TU Munich

"Super-resolution and resolution limits of computational imaging systems", Berkeley, Computational Imaging Lunch

"Active ranking from pairwise comparisons and when parametric models don't help", Berkeley, Berkeley Laboratory for Information and System Sciences (BLISS) Seminar

"Active ranking from pairwise comparisons and when parametric models don't help", Information Theory and Applications Workshop

2016 Super-resolution radar, USC

Press coverage

Jan. 2021 We appeared in the German TV series Galileo for our work on DNA storage, see video.

Nov. 2020 Invited article in the German newspaper "Frankfurter Allgemeine" on DNA as an information technology (article).

Aug. 2020 We stored the first Series of the German TV show "Biohackers" for Netflix on DNA. This was one of the first commercial applications of DNA storage, and received wide press coverage by the German media including the newspaper FAZ, a 8-minute feature in the German TV show "Gut zu wissen" (see video), and a number of blogs such as https://blocksandfiles.com and www.golem.de.

Oct. 2018 We stored Massive Attack's music album Mezzanine on DNA. This was the first commercial application of DNA storage and received press coverage by **Weired** "Massive Attack are releasing an album in a new format: DNA", and **Fortune** "Scientists are coding an electronic music masterpiece into DNA so it can last forever", amongst others.

Nov. 2015 BBC featured a video about us and the DNA storage project in the science news series "the genius behind", the video was broadcasted at BBC worlds news, the channel with the largest audience of any channel: http://www.bbc.com/future/story/20151122-this-is-how-to-store-human-knowledge-for-eternity.

Jan. 2015 Our work on robust DNA data storage was featured in Nature as research highlight and received press coverage by BBC, CNN, and IEEE Spectrum