Matthew J. Hirn

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Research Interests

Pure, applied, and computational harmonic analysis; data science; machine learning

- Mathematical foundations of deep learning (scattering transforms)
- Machine learning and many body physics (quantum chemistry, materials science)
- Geometric methods for high dimensional data analysis (manifold learning)
- Smooth extensions and interpolations, with efficient algorithms (Whitney extensions)

Positions Held

- *Assistant Professor*, Michigan State University
  Department of Computational Mathematics, Science & Engineering
  Department of Mathematics
  2015 – Present
- *Postdoctoral Researcher*, École normale supérieure
  Department of Computer Science
  Mentor: Stéphane Mallat
  2013 – 2015
- *Postdoctoral Associate*, Yale University
  Department of Mathematics, Program in Applied Mathematics
  Mentor: Ronald R. Coifman
  2009 – 2013

Education

- *PhD in mathematics*, University of Maryland, College Park
  Advisors: John J. Benedetto, Kasso Okoudjou
  2004 – 2009
- *BA in mathematics*, Cornell University
  Advisor: Robert Strichartz
  2000 – 2004

AWARDS, FELLOWSHIPS & GRANTS

- DARPA Director's Fellowship (2018 – 2019)
  $249,511 (single PI)
- Editor's Pick article (2018)
  Journal of Chemical Physics
- Kavli Fellow (2017)
  Awarded by the National Academy of Sciences
- Alfred P. Sloan Fellowship (2016 – 2020)
  $55,000 (single PI)
- DARPA Young Faculty Award (2016 – 2018)
  $494,787 (single PI)
- NSF grant #1620216 (2016 – 2019)
  $191,775 (single PI)
- AMS-Simons Travel Grant (2012 – 2014)
  $4,000 (single PI)
- Ann G. Wylie Dissertation Fellowship (2009)
  Awarded by the University of Maryland

ADVISING

UNDERGRADUATE

2018 REU project co-leader on "Machine Learning from Quantum Computing" (MSU):

- Muawiz Chaudhary (undergraduate at WWU)
- Nikhil Shankar (undergraduate at UM, Ann Arbor)

2013 REU project leader on "High Dimensional Data Analysis" (Cornell University)

- Ariel Herbert-Voss (now a graduate student at Harvard)
- Nicholas Marshall (now a graduate student at Yale)
- Frederick McCollum (now an NSF graduate fellow at NYU)
- Christian Smith: (now a graduate student at UW, Madison)
- Keyi Wu: (now a software engineer at Bloomberg LP)
- Wendy Zeng: (now a graduate student at UCSD)

GRADUATE

I am currently advising 4 Ph.D. students:

- Nathan Brugnone: 2nd year CSUS/CMSE (co-advised with Robert Richardson)
- Xavier Brumwell: 2nd year CMSE
- Jieqian He: 2nd year CMSE/Statistics
- Ryan LaRose: 1st year CMSE/Physics

POSTDOCTORAL

I am currently mentoring 3 postdoctoral researchers:

- Anna Little: CMSE (co-mentored with Yuying Xie)
- Michael Perlmutter: CMSE/Mathematics (co-mentored with Mark Iwen)
- Paul Sinz: CMSE

SHORT TERM VISITS

- *Senior Fellow*, Institute for Pure and Applied Mathematics (IPAM)
  For the program on "Understanding Many-Particle Systems with Machine Learning"
  2016 (fall semester)
- *Visiting Assistant Professor*, Cornell University
  Department of Mathematics
  Directed NSF REU on "High Dimensional Data Analysis"
  2013 (summer)
- *Scientific Researcher*, Fields Institute
  For the "Focus Program on Whitney Problems"
  2012 (two weeks)
- *Visiting Researcher*, Institute of Research of Mathematics of Rennes
  For research collaboration
  2011 (three weeks)

PAPERS

Authors are listed in alphabetical order and are equal contributors (per the convention in Mathematics), unless otherwise noted.

JOURNAL

9. Nicholas F. Marshall[1] and Matthew J. Hirn[2].
   Time-coupled diffusion maps.
   Applied and Computational Harmonic Analysis, volume 45, number 3 pages 709–728, 2018.

[1] Primary contributer (first author)
[2] PI for the paper

8. Michael Eickenberg, Georgios Exarchakis, Matthew Hirn, Stéphane Mallat and Louis Thiry.
Solid Harmonic Wavelet Scattering for Predictions of Molecule Properties.
The Journal of Chemical Physics (Editor's Pick), volume 148, pages 241732-1–241732-9, 2018.

7. Matthew J. Hirn, Stéphane Mallat, and Nicolas Poilvert.
Wavelet scattering regression of quantum chemical energies.
Multiscale Modeling and Simulation, volume 15, number 2, pages 827–863, 2017.

6. Ariel Herbert-Voss, Matthew J. Hirn, and Frederick McCollum.
Computing minimal interpolants in $C^{1,1}(\mathbb{R}^d)$.
Revista Matemática Iberoamericana, volume 33, number 1, pages 29–66, 2017.

5. Matthew J. Hirn and Erwan Le Gruyer.
A general theorem of existence of quasi absolutely minimal Lipschitz extensions.
Mathematische Annalen, volume 359, number 3-4, pages 595–628, 2014.

4. Ronald R. Coifman and Matthew J. Hirn.
Diffusion maps for changing data.
Applied and Computational Harmonic Analysis, volume 36, number 1, pages 79–107, 2014.

3. Ronald R. Coifman and Matthew J. Hirn.
Bi-stochastic kernels via asymmetric affinity functions.
Applied and Computational Harmonic Analysis, volume 35, number 1, pages 177–180, 2013.

2. Matthew J. Hirn.
The number of harmonic frames of prime order.
Linear Algebra and Its Applications, volume 432, number 5, pages 1105–1125, 2010.

1. Matthew J. Hirn.
The refinability of step functions.
Proceedings of the American Mathematical Society, volume 136, number 3, pages 899–908, 2008.

Conference and Workshop

All conference and workshop papers are peer reviewed (per the convention in Computer Science and Electrical Engineering), unless otherwise noted.

5. Michael Eickenberg, Georgios Exarchakis, Matthew Hirn and Stéphane Mallat.
Solid Harmonic Wavelet Scattering: Predicting Quantum Molecular Energy from Invariant Descriptors of 3D Electronic Densities.
Advances in Neural Information Processing Systems 30 (NIPS 2017), pages 6540–6549, 2017.

4. Tobias Welp[3], Guy Wolf, Matthew Hirn and Smita Krishnaswamy[4].
A Diffusion-based Condensation Process for Multiscale Analysis of Single Cell Data.
In *ICML Workshop on Computational Biology*, New York, June 24, 2016. 5 pages.

3. Martin Ehler and Matthew J. Hirn.
Sparse endmember extraction and demixing.
In *Proceedings of the IEEE 2012 International Geoscience and Remote Sensing Symposium*, pages 1385–1388, Munich, Germany, July 22–27, 2012.

[3]Primary contributer (first author)
[4]PI for the paper

2. John J. Benedetto, Wojciech Czaja, Martin Ehler, Justin C. Flake, and Matthew J. Hirn.
Wavelet packets for multi and hyperspectral imagery[5]**.**
In *Proceedings of IS&T/SPIE Electronic Imaging 2010, Wavelet Applications in Industrial Processing VII*, San Jose, California, January 2010.

1. John J. Benedetto, Wojciech Czaja, Justin C. Flake, and Matthew J. Hirn.
Frame based kernel methods for automatic classification in hyperspectral data.
In *Proceedings of the IEEE 2009 International Geoscience and Remote Sensing Symposium*, volume 4, pages 697–700, Cape Town, South Africa, July 12–17, 2009.

EXPOSITORY

1. Matthew J. Hirn.
Distinguished lecture series: Assaf Naor on the Lipschitz extension problem.
Fields Notes, volume 12, number 3, page 14, Winter 2013.

PREPRINT

2. Adam Gustafson, Matthew Hirn, Kitty Mohammed, Hariharan Narayanan and Jason Xu.
Structural Risk Minimization for $C^{1,1}(\mathbb{R}^d)$ Regression.
Submitted, 2018.
arXiv.

1. Kevin R. Moon[6], David van Dijk[6], Zheng Wang[6], William Chen, Matthew J Hirn, Ronald R Coifman, Natalia B Ivanova, Guy Wolf[7] and Smita Krishnaswamy[7].
Visualizing Transitions and Structure for High Dimensional Data Exploration.
Submitted, 2018.
Available on bioRχiv, 2017.

UNPUBLISHED

4. A. Tkatchenko[7], M. Afzal, C. Anderson, T. Baker, R. Banisch, S. Chiama, C. Draxl, M. Haghighatlari, F. Heidar-Zadeh, M. Hirn, J. Hoja, O. Isayev, R. Kondor, L. Li, Y. Li, G. Martyna, M. Meila, K.S. Ruiz, M. Rupp, H. Sauceda, A. Shapeev, M. Stöhr, K. R. Müller, S. Shankar[7].
IPAM Program on Machine Learning & Many-Particle Systems - Recent Progress and Open Problems.
Report for the Institute for Pure and Applied Mathematics (IPAM), 2017.

3. Matthew J. Hirn, Nicolas Poilvert, and Stéphane Mallat.
Quantum Energy Regression using Scattering Transforms.
arXiv:1502.02077, 2015.

2. Matthew J. Hirn.
Algorithms for computing the optimal Lipschitz constant of interpolants with Lipschitz derivative.
arXiv:1307.3292, 2013.

[5]Only the abstract is peer reviewed
[6]Primary contributer (first author)
[7]PI for the paper

1. Matthew J. Hirn and David Widemann.
Frames for subspaces of $\mathbb{C}^n$.
arXiv:1410.5206, 2007.

TALKS

All listed talks are invited.

CONFERENCE AND WORKSHOP

25. Understanding Many-Particle Systems with Machine Learning 1st Reunion.
Institute for Pure and Applied Mathematics (IPAM), UCLA.
Solid Harmonic Wavelet Scattering for Prediction of Molecular Properties
June 14, 2018

24. Understanding Many-Particle Systems with Machine Learning 1st Reunion.
Institute for Pure and Applied Mathematics (IPAM), UCLA.
Introduction to Understanding Many-Particle Systems with Machine Learning (evening lecture).
June 11, 2018

23. 7th International Conference on Computational Harmonic Analysis.
Multiscale machine learning for many particle physics with wavelet scattering transforms.
May 15, 2018

22. HKUST IAS workshop on "The Mathematics of Deep Learning."
Three dimensional deep learning and many body physics.
January 8, 2018

21. ICERM workshop on "Geometry and Topology of Data."
Transferring diffusion based manifold learning to trajectories and time varying data.
December 11, 2017

20. CECAM workshop on "Big Data driven Materials Science."
Solid Harmonic Wavelet Scattering.
September 11, 2017

19. The 9th Applied Inverse Problems Conference.
Session on Inverse Problems and Low Complexity Models.
Deep Wavelet Scattering: Towards Mathematical Understanding of Convolutional Networks through Physics, Probability and Manifolds.
June 1, 2017

18. First International Conference on Mathematics of Data Science.
Hong Kong Baptist University.
Learning Many Body Physics with Multiscale, Multilayer Machine Learning Architectures.
March 20, 2017

17. Understanding Many-Particle Systems with Machine Learning Culminating Workshop.
Lake Arrowhead, UCLA.
Scattering Transform Kernels.
December 13, 2016

16. Understanding Many-Particle Systems with Machine Learning Tutorials.
Institute for Pure and Applied Mathematics (IPAM), UCLA.
Wavelet Tutorial, Part II.
September 14, 2016

15. Understanding Many-Particle Systems with Machine Learning Tutorials.
Institute for Pure and Applied Mathematics (IPAM), UCLA.
Wavelet Tutorial, Part I.
September 13, 2016

14. Understanding Many-Particle Systems with Machine Learning Opening Day.
Institute for Pure and Applied Mathematics (IPAM), UCLA.
Multiscale Machine Learning.
September 12, 2016

13. The 11th American Institute of Mathematical Sciences (AIMS) Conference on Dynamical Systems, Differential Equations and Applications.
Orlando, Florida.
Special Session on Harmonic Analysis and Partial Differential Equations.
Deep Wavelet Scattering for Quantum Energy Regression.
July 1, 2016

12. American Physical Society March Meeting 2016.
Baltimore, Maryland.
Session on Predicting and Classifying Materials via High-Throughput Databases and Machine Learning.
Deep Wavelet Scattering for Quantum Energy Regression (invited talk for the session).
March 15, 2016

11. 8th Whitney Problems Workshop.
CIRM, Luminy, France.
Computing Minimal Interpolants in $C^{1,1}(\mathbb{R}^d)$ (with A. Herbert-Voss and F. McCollum).
October 22, 2015

10. PASC15 Conference.
ETH Zürich.
Minisymposium on Big Data Analytics for Novel Materials Discovery.
Quantum Energy Regression by Scattering Transforms.
June 1, 2015

9. Foundations of Computational Mathematics Conference 2014.
Universidad de la República.
Workshop A2: Computational Harmonic Analysis, Image and Signal Processing.
High dimensional learning rather than computing in quantum chemistry.
December 12, 2014

8. 5th International Conference on Computational Harmonic Analysis.
Vanderbilt University.
Minimal $C^{1,1}$ *extensions.*
May 23, 2014

7. Statistics, Mathematics, and Applications Conference.
   Fréjus, France.
   Diffusion maps for changing data.
   September 3, 2013

6. Workshop on Whitney type extension and trace problems.
   The Fields Institute.
   A general theorem of existence of quasi absolutely minimal Lipschitz extensions.
   August 28, 2012

5. Operator Algebras, Frames, and Undergraduate Research: A Conference in Honor of the 70$^{\text{th}}$ Birthday of David R. Larson.
   Texas A&M University.
   Diffusion maps for changing data.
   July 21, 2012

4. Fourth Whitney Problems Workshop.
   College of William and Mary.
   Wells' construction of interpolants in $C^{1,1}(\mathbb{R}^n)$.
   August 4, 2011

3. Mini-Conference in Harmonic Analysis on the Occasion of John Benedetto's 70$^{\text{th}}$ Birthday.
   University of Maryland.
   Harmonic frames of prime order.
   August 21, 2009

2. Recent Advances in Harmonic Analysis and Elliptic Partial Differential Equations.
   University of Virginia.
   Frame based kernel methods for hyperspectral imagery data.
   May 9, 2009

1. Graduation Conference 2009
   University of Maryland.
   Frame based kernel methods for hyperspectral imagery data.
   May 1, 2009

SEMINAR

23. Michigan State University.
    ACRES REU Seminar Series.
    Computational Harmonic Analysis and Data Science.
    June 6, 2018

22. RWTH-Aachen University.
    Center for Computational Engineering Science Seminar.
    Multiscale Machine Learning and Many Body Physics.
    September 18, 2017

21. Shanghai Jiao Tong University.
    Applied Math Seminar.

Multiscale Machine Learning and Many Body Physics.
June 6, 2017

20. Johns Hopkins University.
Data Analysis Seminar.
Learning Many Body Physics with Multiscale, Multilayer Machine Learning Architectures.
March 8, 2017

19. Michigan State University.
Physical Chemistry Seminar.
High Dimensional Learning Rather than Computing in Quantum Chemistry.
November 17, 2015

18. Michigan State University.
Computer Science and Engineering Lecture Series.
High Dimensional Learning Rather than Computing in Quantum Chemistry.
October 9, 2015

17. Michigan State University.
Applied Math Seminar.
Quantum Energy Regression by Scattering Transforms.
September 11, 2015

16. University of Minnesota.
Mathematics Colloquium.
Interpolation for Physical Big Data.
February 26, 2015

15. City College of New York.
Mathematics Colloquium.
Interpolation for Physical Big Data.
February 18, 2015

14. Yale University.
Applied Mathematics Seminar.
High Dimensional Learning rather than Computing in Quantum Chemistry.
February 4, 2015

13. Michigan State University.
Mathematics Colloquium.
Interpolation for Physical Big Data.
January 16, 2015

12. Institut Henri Poincaré.
Analyse non-linéaire et EDP seminar.
Minimal $C^{1,1}$ Extensions.
April 15, 2014

11. École normale supérieure.
Sierra group meeting.
Diffusion based manifold learning (joint talk with Guy Wolf).
October 23, 2013

10. Cornell University.
REU Smorgasbord Seminar.
Diffusion geometry for high dimensional data.
July 3, 2013

9. Yale University.
Analysis Seminar.
Quasi absolutely minimal Lipschitz extensions.
February 21, 2013

8. Cornell University.
Analysis Seminar.
New developments in the theory of absolutely minimal Lipschitz extensions.
December 3, 2012

7. Kansas State University.
Mathematics Colloquium.
Diffusion maps for changing data.
November 29, 2012

6. University of Houston.
Image Analysis Seminar.
Diffusion maps for changing data.
November 5, 2012

5. Vanderbilt University.
Computational Analysis Seminar.
Diffusion maps for changing data.
October 17, 2012

4. University of Maryland.
Norbert Wiener Center Seminar.
Diffusion maps for changing data.
October 2, 2012

3. Bell Labs.
Mathematics Colloquium and Informal Seminar.
Diffusion maps for changing data.
July 26, 2012

2. Duke University.
Applied Mathematics Seminar.
Diffusion maps for changing data.
January 23, 2012

1. École Normale Supérieure de Cachan, Antenne de Bretagne, France.
Groupe de travail "applications des mathématiques,"
Minimal interpolants in $C^{1,1}(\mathbb{R}^n)$.
December 7, 2011

SOFTWARE

3. ScatNet-QM-2D
   Matthew Hirn, Stéphane Mallat, and Nicolas Poilvert.
   Primary developer and author.
   2016.

2. C-1-1-Interpolation
   Frederick McCollum and Matthew Hirn.
   Supervisor and secondary author.
   2014 – 2016.

1. ScatNetLight
   Edouard Oyallon and Matthew Hirn.
   Contributor.
   2015 – 2016.

TEACHING

MICHIGAN STATE UNIVERSITY

- MATH 994-003: Computational Harmonic Analysis and Data Science.
  Topics level graduate course that I developed.
  Spring 2018

- CMSE 820: Mathematical Foundations of Data Science.
  New qualifying exam course for the Department of Computational Mathematics, Science & Engineering (CMSE), which I developed. In addition to teaching the course, I wrote two qualifying exams associated with it and organized weekly summer review sessions.
  Spring 2017

- NSC 204 / CMSE 201: Introduction to Computational Modeling.
  Flipped class.
  Spring 2016

- MATH 414: Linear Algebra II.
  Fall 2015

YALE UNIVERSITY

- MATH/AMTH 244: Discrete Mathematics.
  Fall 2010

- MATH/AMTH 244: Discrete Mathematics.
  Fall 2009

UNIVERSITY OF MARYLAND

- Review Course for Analysis PhD Qualifying Exam.
  Summer 2007

- Math 111: Introduction to Probability.
  Spring 2006
- Math 111: Introduction to Probability.
  Fall 2005

SERVICE

CONFERENCE AND SEMINAR ORGANIZATION

- Organized mini-session on "Kernel Learning and Harmonic Analysis"
  Held during the "Culminating Workshop of the IPAM long program on Understanding Many-Particle Systems with Machine Learning"
  December 2016
- Co-organizer of the 8^{th} Whitney Problems Workshop 2015
  Held at the Centre International de Rencontres Mathématiques (CIRM)
  October 2015
- Applied Mathematics Seminar co-organizer
  Yale University
  2012 – 2013
- Norbert Wiener Center Seminar co-organizer
  University of Maryland
  2007 – 2008

GRANT EVALUATION

- Reviewer for DOE grant proposals
  2017
- Joint NSF/NIH panel member
  2016

JOURNAL REFEREE

- Applied and Computational Harmonic Analysis
  "Excellent reviewer" (top 10^{th} percentile)
  2011 – 2018
- European Journal of Operational Research
  2018
- IEEE Transactions on Circuits and Systems for Video Technology
  2018
- IEEE Signal Processing Letters
  2013 – 2014
- IEEE Transactions on Information Theory
  2012

- Linear Algebra and Its Applications
  2009
- Neural Computation
  2013
- NPJ Computational Materials
  2017
- Proceedings of the American Mathematical Society
  2011
- SIAM Journal on Applied Dynamical Systems
  2013
- Signal Processing
  2014

University Committees

- Chair of the CMSE Undergraduate Studies Committee
  2017 – 2018
  2018 – 2019
- CMSE Long Term Steering Committee
  2017 – 2018
- CMSE/CSE/ECE Hiring Committee
  Connected and autonomous networked vehicles for active safety (CANVAS)
  2017 – 2018
- CMSE/CSE Hiring Committee
  Deep learning
  2017 – 2018
  2018 – 2019
- Mathematics Hiring Committee
  Fixed term to tenure stream conversion
  2017 – 2018
- CMSE/ChEMS Hiring Committee
  Computational materials science
  2016 – 2017

University Outreach

- Panel member on "Getting Started at MSU"
  University wide new faculty orientation at Michigan State University
  August 23, 2018
- CMSE Department promotional talk
  Shanghai Jiao Tong University
  June 6, 2017

- CMSE Department promotional talk
  Fudan University
  June 5, 2017

- Panel member on "Getting Grants"
  Michigan State University, College of Natural Science.
  September 9, 2016

- Panel member on "How to look for an academic job"
  Michigan State University, Department of Mathematics.
  November 5, 2015

- Speaker at Putnam Exam review sessions
  Yale University
  Fall 2009