Paul Louis Bendich

Curriculum Vitae

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Research Interests: Computational Topology and Geometry, Machine Learning, Statistics, Multi-modal Data Analysis

Education

Duke University — Durham, NC
Ph.D. in Mathematics — 8/2003–8/2008

Duke University — Durham, NC
M.A. in Mathematics — 8/2003–2/2005

Grinnell College — Grinnell, IA
B.A. in Physics — 8/1997–5/2001

Employment

- Assistant Research Professor (regular-rank), Department of Mathematics, Duke University, 4/2014- present
- Associate Director for Curricular Engagement, the Information Initiative at Duke (iiD), 7/2014- present
- Chief Mathematician, Geometric Data Analytics, Inc., 10/2014- present
- Visiting Assistant Professor, Department of Mathematics, Duke University, 1/2011- 3/2014
- Postdoctoral Associate, IST Austria, 8/2009–12/2010.
- Instructor, Department of Mathematics, Pennsylvania State University, 8/2008–7/2009.

Awards and Grants

- Faculty Honoree, Seniors for Duke Gift Campaign, Duke, March 2017.
- Gold Prize, Natural Sciences Category, Reimagine Education Conference, December 2016.
- PI, *Topological Signal Analysis for Multi-modal Data Analysis*, Air Force Research Laboratory, FA8760-16-C-0220. $63,513, 8/01/2016-4/30/2017.
- co-PI (John Harer, PI), *Topological Data Analysis and Machine Learning with Community Accepted Features*, National Science Foundation, BIGDATA: F: DKA: CSD: 1444791. $599,508, 9/01/2014-8/31/2018.
- co-PI (John Harer, PI), *Geometric, Topological, and Statistical Methods for Analysing Massive Datasets*, National Science Foundation, Research Training Grant, $2,013,619, 7/1/2011-7/31/2017.
- Captain L.P. and Barbara Smith Award for Graduate Teaching Excellence, Duke, December 2007.

Publications

Under Review

- Christoper J. Tralie, Paul Bendich, Abraham Smith, Jay Hineman, Nathan Borggren, Peter Zulch, and John Harer. *Geometric Cross-Modal Comparision for Heterogeneous Sensor Data.* submitted to IEEE Aerospace Conference.
- Denis Garagi, Jake Peskoe, Fang Liu, John Harer, Nathan Borggren, Jay Hineman, Kenneth Ball, Paul Bendich, Peter Zulch, Mike Claffey, and Bradley J. Rhodes. *Upstream Fusion of Multiple Sensing Modalities using Machine Learning and Topological Analysis: An Initial Exploration.* submitted to IEEE Aerospace Conference.
- Abraham Smith, Paul Bendich, John Harer, and Jay Hineman. *Supervised Learning of Labeled Pointcloud Differences via Cover-tree Entropy Reduction.* submitted to Discrete and Computational Geometry, arXiv 1702.07959

Journal Publications

- Paul Bendich, Sang Chin, Jesse Clarke, John Harer, Elizabeth Munch, David Porter, David Rouse, Nate Strawn, and Adam Watkins. *Topological and Statistical Behavior Classifiers for Tracking Applications*, IEEE Transactions on Aerospace and Electronic Systems, 52(6):2644-2661, 2016.
- Paul Bendich, J.S. Marron, Ezra Miller, Sean Skwerer, and Alex Pieloch. *Persistent Homology Analysis of Brain Artery Trees*, Annals of Applied Statistics, 10(1):198-218, 2016.
- Liz Munch, Kate Turner, Paul Bendich, Sayan Mukherjee, Jonathan Mattingly, and John Harer. *Probabilistic Frechet Means and Statistics on Vineyards*, Electronic Journal of Statistics, 9:1173-1204, 2015.
- Paul Bendich, Herbert Edelsbrunner, Dmitriy Morozov, and Amit Patel. *Homology and Robustness of Level and Interlevel Sets*, Homology, Homotopy and Applications,15(1):51-72, 2013.
- Paul Bendich, Sergio Cabello, and Herbert Edelsbrunner. *A Point Calculus for Interlevel set Homology*, Pattern Recognition Letters, 1436-1444, 2012.
- Paul Bendich, Taras Galkovskyi, and John Harer. *Improving Homology Estimates with Random Walks.* Inverse Problems 27, 2011.
- Paul Bendich and John Harer. *Persistent Intersection Homology*, Foundations of Computational Mathematics, 11(3):305-336, 2011.
- Paul Bendich, Herbert Edelsbrunner, and Michael Kerber. *Computing Robustness and Persistence for Images*, IEEE Transactions on Visualization and Computer Graphics, 1251-1260, 2010.

Book Chapters

- Paul Bendich, Ellen Gasparovic, John Harer, and Christopher J. Tralie. *Scaffoldings and Spines: Organizing High-Dimensional Data Using Cover Trees, Local Principal Component Analysis, and Persistent Homology*, in *Research in Computational Topology*, AWM-IMA Springer Series, to appear January 2018.

Conference Proceedings Publications

- Paul Bendich, Ellen Gasparovic, John Harer, and Christopher J. Tralie. *Geometric Models for Musical Audio Data*, Proceedings of the 32nd International Symposium on Computational Geometry, multimedia submission, 2016.
- Christopher J. Tralie and Paul Bendich. *Cover Song Identification with Timbral Shape Sequences*, Proceedings of the 2015 International Symposium on Music Information Retrieval, 38-44, 2015.

- Paul Bendich, Ellen Gasparovic, John Harer, Rauf Ismailov, and Linda Ness. *Multi-scale Local Shape Analysis and Feature Selection for Machine Learning Applications*, Proceedings of the 2015 International Joint Conference on Neural Networks, 1-8.
- Paul Bendich, Bei Wang, and Sayan Mukherjee. *Local Homology Transfer and Stratification Learning*, Proceedings of the Twenty-Third Annual ACM-SIAM Symposium on Discrete Algorithms 1355-1370, 2012.
- Paul Bendich, Herbert Edelsbrunner, Michael Kerber, and Amit Patel. *Persistent Homology under Non-Uniform Error*, Proc. 35th International Symposium on Mathematical Foundations of Computer Science, 12-23.
- Paul Bendich, Herbert Edelsbrunner, Dmitriy Morozov, and Amit Patel. *The Robustness of Level Sets*, Proc. 18th European Symposium on Algorithms, 1-10, 2010.
- Paul Bendich, David Cohen-Steiner, Herbert Edelsbrunner, John Harer, and Dmitriy Morozov. *Inferring Local Homology from Sampled Stratified Spaces*, Proc. 48th Symposium on Foundations of Computer Science, 2007, pp. 536-546.

Dissertation

- Paul Bendich. *Analyzing Stratified Spaces Using Persistent Versions of Intersection and Local Homology*, Ph.D. Thesis, Duke University,2008.

Undergraduates Mentored

- *Data+ Program, 2015-present*
  - approximately 70 students per summer.
- *Topology, Statistics, and Brain Data*, Data RTG, Summer 2014:
  - Carmen Cox (Duke)
  - Derrick Nowak (Duke)
  - Henry Farrell (Cornell)
  - Dong-Hwan Moon (Williams)
  - Alex Pieloch (Duke)
- *Multi-scale Topology for Signals and Images*, Data RTG, Summer 2013:
  - Bingxi Lin (Bryn Mawr)
  - Michael Ogez (Duke)
  - Benjamin Dreyzen (UNC)
  - Joshua Martin (UNC-Greensboro)
- Marshall Ratliff, Duke PRUV 2015
  - Senior Thesis: *Introducing the Cover Tree to Music Information Retrieval*
- Bryan Jacobsen, Duke PRUV 2012
  - Senior Thesis: *A Fast Approximate Algorithm for Local Homology*

Pedagogical Contributions

Courses Designed or co-Designed

- *Data Science Math Skills*, with Daniel Egger, Coursera Online Course, debuted Spring 2017.
- *Introduction to Data and Decision Science*, with Stacy Tantum, to be required of all Sophomores in Pratt School of Engineering, Duke, to debut Spring 2018.
- *The Emerging Science of Complex Data (First-Year Seminar)*, Math 89S, Duke; taught Spring 2012 and Spring 2013.
- *Computational Topology*, with Herbert Edelsbrunner, IST Austria, taught Fall 2010.

Courses Substansially re-Designed

- *Introduction to High-dimensional Data Analysis*, originally designed by Mauro Maggionni, Math 465, Duke, taught Fall 2016 and Fall 2017.
- *Topology with Applications*, originally designed by John Harer, Math 412, Duke; taught Fall 2012, Fall 2014, Spring 2016.

Other Courses Taught

- *Linear Algebra*, Math 221, Duke, Fall 2013 and Spring 2014.
- *Combinatorics*, Math 371, Duke, Fall 2015.
- *Topology*, Math 411, Duke, Fall 2011.
- *Linear Algebra*, Penn State, Spring 2009.
- *Business Calculus II*, Penn State, Spring 2009.
- *Calculus I*, Penn State, Fall 2008.
- *Linear Algebra and Differential Equations*, Duke, Summers 2008 and 2007.
- *Laboratory Calculus II*, Math 112, Duke, Summer 2006, Spring 2006.
- *Laboratory Calculus I*, Math 111, Duke Fall 2005.

Departmental and University Service

- Coordinator, Data+ Program, The Information Initiative at Duke (iiD), 7/2014–Present.
- Coordinator, Data Expeditions Program, The Information Initiative at Duke (iiD), 7/2014–Present.
- Member, Curriculum Committee, Masters in Interdisciplinary Data Science, Duke, 1/2017–Present.
- Member, STEM Pathways Committee, Duke, 7/2016–Present.
- Member, DoMATH Summer Research Program Committee, 10/2016–Present.
- Celebrity Judge, ASA Datafest, Duke, 4/2015–Present
- Member, Bass Connections Program Development Group, 7/2015–2/2016
- Coordinator, Summer Undergraduate Research Program, Duke, 1/2011–6/2014
- Organizer, Data Seminar/Data Dialogue, Duke, 8/2011–Present.
- Member and Founder, Graduate Student Calculus Curriculum Committee, Duke, Fall 2008.

Workshops Organized

- Research Experiences for Undergraduate Faculty (REUF), workshop with AIM on "Mathematics of Data", Duke, July 2016.
- Spring Topology and Dynamics Conference, Session on Applied Topology, University of Richmond, March 2014.
- LDHD: Topological Data Analysis, workshop at SAMSI, Feburary 2014.
- Computational Topology, workshop at Symposium on Computational Geometry, Chapel Hill, NC, June 2012.
- Computational Topology, workshop at SIAM Conference on Applied Algebraic Geometry, Raleigh, NC, October 2011.

Invited Talks

- *Doing Machine-Learning and Statistics with Topological and Geometric Features: three examples*, Mathematics Department Colloquium, University of North Carolina at Greensboro, October 2017.
- *Supervised Learning for Labeled Pointclouds via Cover-tree Entropy Reduction*, Workshop on Computational Geometry and Topology, Foundations of Computational Mathematics, Universitat de Barcelona, July 2017.
- *Shape, Data, the Brain, and Music*, Undergraduate Mathematics Seminar, Grinnell College, April 2017.
- *Cross-disciplinary Data Science Training*, Faculty Seminar, Grinnell College, April 2017.
- *Constructing Data Science Pipelines*, Q-STEP, University of Exeter, April 2017.
- *The Data+ Program*, Reimagine Education Conference, Philadelphia, PA, December 2016.
- *Using Shape in Data with Topology and High-Dimensional Geometry*, team-talk with Christopher J. Tralie, Lunch-and-Learn, SAS, October 2016.
- *Cross-disciplinary Data Science Training: Summer Immersions, Brief Dips, and Consistent Pipelines*, Laboratory of Analytics Sciences, July 2016.
- *Topological Features for Machine Learning and Statistics: Brain Arteries and Driver Behavior*, World Congress on Probability and Statistics, Fields Institute, July 2016.
- *Topological Features for Machine Learning*, team-talk with Nate Strawn, Data Seminar, Duke University, April 2014.
- *Persistent Local Homology: Theory, Applications, Computational Innovations*, Workshop on Topology and Statistics, SAMSI, February 2014.
- *Persistent Homology: theory and computational innovations*, Algorithm Theory Seminar, North Carolina State University, November 2013.
- *Stratifications and Persistent Homology*, SATANA Seminar, University of Illinois at Urbana-Champaign, November 2013.
- *Brain-artery Trees and Persistent Homology*, iiD Seminar, Duke, November 2013.
- *Probabilistic Frechet Means and Statistics on Vineyards*, Workshop on Applied Algebraic Topology, Bremen, August 2013.
- *Stratification Learning via Local Homology Inference*, AMS Sectional, Boulder, CO, April 2013.
- *Tracking with Persistence*, BANFF, October 2012.
- Φ-*SoMap*, AMS-MAA Joint Meetings, Boston, MA, January 2012.

- *Persistence Diagrams and the Information they Carry*, Data Seminar, Duke, August 2011.
- *Stratification Learning via Local Homology Inference*, INRIA-Saclay, October 2010.
- *The 2-Point Formula*, Workshop on Computational Topology in the Image Context, Graz, Austria, October 2009.
- *Elevation on Stratified Spaces via Intersection Homology*, DARPA TDA meeting, Santa Barbara, CA, January 2009.
- *Teaching Without much Lecturing*, Education Seminar, Penn State, January 2009.
- *Persistent Intersection Homology*, Algorithms Seminar, Duke, March 2008.
- *Local Homology Vineyards*, DARPA TDA meeting, Santa Barbara, CA, January 2008.
- *Persistence*, Grad-Fac Seminar, Duke, October, 2007.
- *Persistent Local Homology*, DARPA TDA meeting, Santa Barbara, CA, January 2006.

Professional Service

- Reviewer for Journal of Applied and Computational Topology
- Reviewer for Journal of Topology and Analysis
- Reviewer for SIAM Journal of Computing
- Reviewer for Symposium on Computational Geometry
- Reviewer for Symposium on Artificial Intelligence and Statistics
- Reviewer for Experimental Mathematics
- Reviewer for Foundations of Computational Mathematics
- Reviewer for Inverse Problems
- Reviewer for Discrete and Computational Geometry
- Reviewer for Revista Matematica Complutense