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Preview of Award 1934568 - Annual Project Report

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Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1934568
Project Title:	HDR TRIPODS: UC Davis TETRAPODS Institute of Data Science
PD/PI Name:	Naoki Saito, Principal Investigator Annamaria B Amenta, Co-Principal Investigator Chen-Nee Chuah, Co-Principal Investigator Thomas Chun Man Lee, Co-Principal Investigator
Recipient Organization:	University of California-Davis
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Submitting Official (if other than PD\PI):	N/A
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Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	N/A

Accomplishments

*** What are the major goals of the project?**

The UC Davis TETRAPODS Institute of Data Science (UCD4IDS)---composed of thirty-five researchers (four PIs and

thirty-one senior personnel) coming from four departments (Computer Science, Electrical & Computer Engineering, Mathematics, and Statistics)---will break interdepartmental barriers and promote interdisciplinary research collaborations among faculty members, postdocs, and graduate students. Our project will encourage innovative and robust research, and provide education and mentoring of graduate students and postdocs in data science.
In particular, research at the UCD4IDS will focus on three broad themes: 1) Fundamentals of machine learning directed toward biological and medical applications; 2) Optimization theory and algorithms for machine learning including numerical solvers for large-scale nontrivial learning problems; and 3) High-dimensional data analysis on graphs and networks.
The technical goals of the above themes are: 1) geometric understanding of high-dimensional data, which may allow efficient (re)sampling from manifolds representing certain phenomena of interest and classifying subtle yet critical differences that often appear in biological and medical applications; 2) providing theoretical guarantees and efficient numerical algorithms for non-convex optimization, which is crucial to machine learning; and 3) deepening understanding of how local interactions between individual entities (e.g., neurons) lead to global coordination and decision making.
Students and postdocs engaged in this project will be trained to be the next generation of interdisciplinary data scientists: they will gain deep knowledge of some focused areas, and at the same time, broaden their perspectives in other diverse fields. The UCD4IDS will bring in the insights gained by the experience of the faculty members in the four primary departments as well as application fields such as neuroscience, medical and health sciences, and veterinary medicine.

*** What was accomplished under these goals and objectives (you must provide information for at least one of the 4 categories below)?**

Major Activities:

- Conducted research; prepared and published some of our results; presented and disseminated some of our results at conferences and seminars
- Initiated many UC Davis internal collaborations
- Collaborated with three UC Davis groups that engage in data science research and education: *Center for Data science and Artificial intelligence Research (CeDAR)*; *UC Davis DataLab*; and the following two NSF-funded institutes: *AI Institute for Next Generation Food Systems (AIFS)*; and *HSI Strategic Innovation Summit for Advanced Research and Instruction in Artificial Intelligence and Quantum Information Sciences (HSI-SIS)*
- Organized online seminar series related to data science throughout the academic quarters: the Mathematics of Data and Decision at Davis (MADDD) seminars; the Statistics seminars
- Organized annual Joint Mathematics/Statistics Colloquium
- Organized reading seminars on the subjects closely related to the project
- Maintained and constantly updated a website dedicated to our UCD4IDS
- Selected 26 graduate students among our three departments (ECE: 3; Math: 12; Stat: 11) and supported them partially as Graduate Student Researcher
- Accounts of 26 users from our group have been created on the *GPU cluster in our UC Davis High Performance Computing (HPC) Core Facility*

Specific Objectives:

1) Improve our geometric understanding of high-dimensional data, which may allow efficient (re)sampling from manifolds representing certain phenomena of interest and classifying subtle yet critical differences that often appear in biological and medical applications
2) Investigate and develop data harnessing, feature selection, statistical unsupervised learning, data sampling/streaming methodologies and algorithms
3) Provide theoretical guarantees and efficient numerical algorithms for non-convex optimization, which is crucial to machine learning
4) Investigate and develop tools for analyzing hypergraphs, tensors, and high-volume neural data, detecting anomalies/changes over networks, analyzing network structures via random matrix theory, and making cloud-based machine learning more efficient
5) Launch more internal collaborations within our four disciplines
6) Guide postdocs to become more independent data scientists who can contribute to

our overall aims
7) Guide graduate students for data science research and education

Significant Results: The numbering corresponds to that of Specific Objectives section.

1) Amenta(CS)/Hass(Math)/Koehl(CS) developed a new method based on statistical physics for solving the balanced/unbalanced optimal transport problems as well as the 2D assignment problem. This new fast, robust, and provably convergent method has broadened the field of applications of optimal transport, now including partial 2D image and 3D shape comparisons, as well as partial protein sequence and protein structure comparisons.

Arsuaga(Math/MCB) and Vazquez(Math/MMG) developed a new line of research that combines topological data analysis, genomics and biophysics to track the evolution and fitness of the spike (S) protein of the coronavirus SARS-CoV2.

Chuah(ECE) explored the semi/self-supervised learning to address class imbalance issues in health analytics problems. She investigated a smoothing weighting scheme and proposed an algorithm without assumptions on the unlabeled set. Also, she studied the deep reinforcement learning based traffic signal controller on air quality using real traffic demands on city-level road networks and the vulnerabilities of these systems.

De Loera(Math) proposed a probabilistic model for understanding time series where one is making chronological samples. An example is bird watching. Suppose we observed types of birds during a season. A birdwatcher may want to estimate the likelihood of observing specific species at an overlapping time interval. He proposed a new geometric model to answer such questions using random interval graphs.

Jiang(Stat) worked on small area (SA) models (allocation of resources to subgroups in a population) in the class of spatial linear mixed models. His unbiased mean-squared prediction error estimators performed well on physician visits data for Total Respiratory Morbidity conditions in Manitoba, Canada.

Polonik(Stat) explored the geometry of kernel PCA (KPCA) and showed KPCA possesses orthogonal cone structure on the population level.

Rademacher(Math) proposed a new algorithm for tensor decomposition and applied the new algorithmic ideas to blind deconvolution and Gaussian mixture models.

2) Ghiasi(ECE) built a third generation prototype of their transabdominal fetal oxygen saturation measurement technology. The device was validated in gold standard large animal models. He developed fetal signal isolation techniques, which are essential for estimation of SpO2 from noisy measurements that contain both maternal and fetal information.

Hsieh(Stat) developed algorithms for mimicking data matrices of data types: continuous, categorical and their mixed. Data's authentic deterministic/stochastic structures are discovered for resolving fundamental problems of reliability and uncertainty evaluations under Categorical Exploratory Data Analysis.

Lopes(Stat) worked on bootstrap methods in two main application areas: high-dimensional inference, and error estimation for randomized algorithms. He established some of the fastest known rates for the central theorem and bootstrap

approximation in high dimensions and a dimension-free bound on the rate of approximation of the leading eigenvalue of a sample covariance matrix with low effective rank.

Y.J.Lee(CS) proposed a novel adaptive content-aware low-pass filtering layer in convolutional networks, which predicts separate filter weights for each spatial location and channel of the feature maps. The approach effectively avoids aliasing while preserving useful information for image classification and segmentation.

Rajaratnam(Stat) completed developing a theory of differential calculus on the space of countable labeled graphs. This rigorous mathematical approach lays the foundation for differential calculus on such spaces.

3) Strohmer(Math) developed a method for the generation of synthetic data, which is computationally efficient, comes with provable privacy guarantees, and rigorously quantifies data utility, thereby demonstrating that a relaxed version of an NP-hard problem related to differential privacy has a feasible and elegant solution.

Fannjiang (Math) developed theoretical guarantee and efficient numerical algorithms for nonconvex optimization in phase retrieval and ptychography whose global optimizer is unique up to a minimum class of ambiguity depending on the prior information.

Balasubramanian(Stat) proved results on hypergraphons, inference for stochastic zeroth-order algorithms, inference for SGD with dependent data, and provable sampling from heavy-tailed densities which broaden the understanding to these algorithms and their applications in statistics and deep learning.

Ma(Math)/Lai(ECE) studied optimization algorithms for optimal transport problems. Specifically, they designed Riemannian optimization algorithms for solving the projection robust optimal transport problem, which can be cast as a minimax problem over Grassmann manifold. Their algorithms significantly outperformed existing methods.

Koeppe (Math) derived complete characterization and approximation theory of maximal general dual feasible functions for combinatorial optimization problems, and effectively described spaces of cut-generating functions as topological manifolds.

4) Chaudhuri(Math/NPB) studied collective computation in distributed neural systems, which is the potential for massive parallelism—a network of neurons can simultaneously process information much faster than a sequential strategy. He has shown that recurrent neural network architectures can exploit such parallel information processing to choose the best of a set of N options in O(log N) time.

Chen(Stat) developed a potential outcome framework for causal inference with point-process treatments, and analyzed the varying frequencies underlying sharp wave-ripples in mice hippocampus.

T.Lee(Stat) developed novel uncertainty quantification methods for graphon estimation, high-dimensional multi-task learning, and high-dimensional principal component regression. He has also developed a new method for simultaneous change point detection and node clustering for time series of graphs.

Le(Stat) proposed a linear regression model with nonparametric network effects

and an efficient mixing strategy for arbitrary network models whose predictive performances are as good as the oracle estimate.

Li(Stat) studied the sample size conditions for the well-known Chow-Liu algorithm to exactly recover the equivalence class of the polytree (i.e., directed acyclic tree) under Gaussian/sub-Gaussian models, and derived the error rate for the estimation of the inverse correlation matrix under such models.

Saito(Math) completed lifting the time-frequency adapted Haar-Walsh wavelet packets, the smooth wavelet packets, and the local cosine transform to the graph setting.

Sharpnack(Stat) extended the contextual multiarmed bandit in which the player is presented with features to guide his/her actions to handle non-stationarity and to work in linear computation time.

Results from our postdocs:

Wang(ECE) explored some model-based approaches to medical imaging reconstruction problems. Numerically, he designed a specific splitting scheme, under which he can prove subsequential and global convergence. Experimentally, he demonstrated visible improvements of L1/L2 over L1 and other nonconvex regularizations for image recovery from low-frequency measurements.

Roy(Stat) showed that under over-parametrization, several standard stochastic optimization algorithms escape saddle-points and converge to local-minimizers much faster thanks to their capability to interpolate the training data.

Schonsheck(Math) applied continuous/discrete differential geometry in machine learning and data science. He published a paper on a highly accurate method to register/compare non-isometric surfaces, and worked on auto-regressive generative models for 3D meshes and geometric graphs, geometric disentanglement, and deformable convolutional networks on manifold-structured data.

Key outcomes or Other achievements:

5) Launch more internal collaborations within our four disciplines:

During this period the following new collaborations within UC Davis have been initiated by the participants on this grant, which should be considered as key outcomes. Note that we are not listing those already listed in our last year's report.

+ Arsuaga/Vazquez(Math/MCB): with Daniel Cox (Physics) and Michael Toney (Chemistry) for the development of computational and experimental methods to track the evolution of SARS-CoV2 (Funded by the CeDAR Seed Grant and NSF grants on COVID-19).
+ Aue(Stat): with Troy Magney (Plant Sciences) on adapting large-scale simulations of the global carbon cycle for the prediction of more local carbon concentrations in the California Sierra Nevada.

+ Balasubramanian/T.Lee(Stat): with Tang (Stat, grad student) on high-probability bounds for stochastic Frank-Wolfe algorithm.

+ Balasubramanian/Aue/T.Lee(Stat): Roy (Stat, postdoc) on inference for SGD algorithm with dependent data streams.

+ Chaudhuri(Math/NPB): with Randall O'Reilly (Psychology/Computer Science) on using synaptic failures to sample from probabilistic models.

+ Chuah(ECE): with Michael Zhang (Civil & Environmental Eng.) and Sean Peisert (CS) on the use of differential privacy to protect use trajectory data while maintaining utility.

+ Drake/Rajaratnam(Stat) on modeling gerrymandering congressional districts, which can identify gerrymandering in districting plans and correlated partisan bias with racial bias.

+ Le(Stat): with Thien-Huong Thi Ninh (Sociology) on prediction of students' success based on the online social interaction.

+ Paul/T.Lee(Stat) on modeling of vector random fields observed on a sphere;

+ Paul/Aue(Stat) on hypothesis testing for network structures based on random matrix theory

+ Paul/Jiang(Stat) on heritability and coheritability estimation from genetic data through high-dimensional linear mixed effects models using random matrix theory.

+ Paul/Burman/Balasubramanian(Stat) on shrinkage-based prediction strategies for high-dimensional linear models.

+ Paul(Stat): with Jie Peng(Stat) on estimation of covariance matrices of high-dimensional random vectors through determination of latent graphical structures.

+ Paul(Stat): with Karen McDonald/Somen Nandi(Chem. Eng.) on developing methods for analysis of variability of biochemical processes.

+ Polonik(Stat)/De Loera(Math) on stochastic Tverberg theorems to infer separability conditions for classification based on logistic regression.

+ Sharpnack(Stat): with Miriam Nuno (Epidemiology) leading the Healthy Davis Together (HDT) modeling team to provide statistical and modeling support to the HDT initiative to combat COVID-19 in Davis, including publishing findings.

+ Strohmer(Math): with Krystle Lynn Reagan (Veterinary Med) on enhancing early diagnosis of leptospirosis in dogs using machine learning.

+ Strohmer(Math): with Rachael Calcutt (UCD Health) and Jason Adams (UCD Health) on algorithms for constructing heterogeneous, dynamic synthetic data with special emphasis on applications in Critical Care.

Also during this review period, some of the UCD4IDS members received the following noteworthy awards:

+ P. Burman (Stat) elected as a 2021 IMS Fellow

+ R. Chaudhuri (Math) won 2021 Sloan Research Fellowship

+ Y. J. Lee (CS) and his students received the Best Paper Award (1 of 670

submissions) at the British Machine Vision Conference (BMVC) 2020 for their work on a novel adaptive content-aware lowpass filtering layer in convolutional neural networks for image classification.

+ I. Tagkopoulos (CS) won the NSF National AI Institutes grant and established the AI Institute for Next Generation Food Systems (AIFS)

*** What opportunities for training and professional development has the project provided?**

6) Guide postdocs to become more independent data scientists who can contribute to our overall aims

* For this purpose, we asked our postdocs to organize two seminar series:
- AI and Biomedical Imaging monthly seminar (Winter 2021) by Chao Wang (ECE);
and
- Mathematics of Data and Decision at Davis (MADDD) weekly seminar (Spring 2021) by Stefan Schonsheck (Math).
They got to know various scientists and engineers within and outside of UC Davis, and learned to interact with the speakers, videotaped their talks, collected their talk slides, and put these to a website for dissemination purposes.

* In addition, our postdocs gave 7 conference/seminar talks altogether as reported in the dissemination section.

7) Guide graduate students for data science research and education
* We have organized two regular weekly seminar series throughout the year, i.e.,
The Mathematics of Data and Decisions at Davis (MADDD) seminars and the Statistics Seminars. These seminars are targeted toward not only faculty experts but also graduate students interested in data science and machine learning. Many of these talks, especially, the MADDD seminar talks, were videotaped and placed on a public website for dissemination purposes.

* Department of Mathematics is now offering a new graduate course on data science:
- MAT 270: Mathematical Foundation of Data Science
Course description: Mathematical methods and algorithms that are fundamental to a variety of data science applications. Theoretical foundations and inner workings of popular algorithms used in data science, machine learning, and artificial intelligence. Implementation and application of these algorithms to real-world data sets.

* Department of Statistics is also offering a new graduate course on data science:
- STA 208: Statistical Methods in Machine Learning
Course description: Focus on linear and nonlinear statistical models. Emphasis on concepts, methods, and data analysis. Topics include resampling methods, regularization techniques in regression and modern classification, cluster analysis and dimension reduction techniques. Use professional level software.

The enrollment sizes of both courses are clearly way greater than normal graduate courses. For example, MAT 270 in Spring 2021 had 42 enrolled students
(Math/Applied Math:24; Stat:12; CS: 3; ECE: 2; Others: 1) while STA 208 in Spring 2021 had 73 enrolled students (Applied Math: 5; Stat: 37; CS: 1; ECE: 14; Others: 16). These distributions clearly indicate the interdisciplinary nature of these courses.

* UC Davis DataLab, with which we collaborate, provided several useful workshops on programming languages and software tools such as Python, R, Git. Our graduate students benefited by these.

*** Have the results been disseminated to communities of interest? If so, please provide details.**

Beyond our publications and other products listed in the Products section, *we gave more than 100 seminar talks, conference/workshop presentations during this review period (most of them via online), despite the COVID restrictions.*

Below is a partial list of such talks.

Arsuaga(Math/MCB): ICLR 2021 Workshop on Geometrical and Topological Representation Learning Virtual meeting 05/07/2021
NSF DMS Mathematics Division COVID-19PI meeting, 06/25/2020
NSF MPS Chemistry Division COVID-19 PI Meeting, 08/04/2020
Annual Conference of the Southern Africa Mathematical Association (SAMSA), 11/23/2020-11/25/2020
Spring Assembly, College of Sciences and Mathematics. Fresno State Univ., 01/16/2021
Research Seminar, Department of Mathematics. UC Davis, 01/26/2021
Radio interview on SARS-CoV2. Science: Candle in the night, 04/21/2021

Aue(Stat): Columbia Univ., New York, October 2020
Statistics Seminar, Lancaster Univ., UK, November 2020
CM Statistics, King's College, London, UK, December 2020
Statistics Seminar, King Abdullah Univ. of Science and Technology, Saudi Arabia, March 2021
Research Training Group/Graduiertenkolleg 2131 Seminar, Ruhr Universitat Bochum, TU Dortmund, Universitat Duisburg-Essen, Germany, June 2021
63rd ISI World Statistics Congress, Seoul, South Korea, July 2021

Balasubramanian(Stat); UC Davis CeDAR Conference, May 2021
Argonne National Laboratory, Chicago, April 2021
Halıcıoğlu Data Science Institute (HDSI), UC San Diego, April 2021
Center of Applied Mathematics (CMAP) CNRS, Ecole Polytechnique, April 2021
HKBU Virtual Conference on Mathematics, Statistics and Data Science, Hong Kong Baptist Univ. April 2021
Oak Ridge National Laboratory, Tennessee, March 2021
Optimization under Uncertainty: Learning and Decision Making, BIRS, January 2021
Two Presentation at NeurIPS, Dec. 2020

Chaudhuri(Math/NPB): NYU Swartz seminar, 2020/09/25,
NeurIPS Spotlight presentation, 2020/12/07,
UC Davis Math Conference talk, 2021/01/28,
NSF TRIPODS PI meeting talk, 2021/06/11,

Chen(Stat): Center for Statistical Science, Peking Univ., Apr. 2021
WNAR/IMS/JR Annual meeting, Jun. 2021

Chuah(ECE): San Francisco Bay ACM Chapter (10,712 members), monthly seminar, April 21, 2021 (130 attendees), Streaming to YouTube SFBay ACM Channel
Oregon Health & Science University (OHSU) Autism Seminar Series, April 26, 2021
Health Data Science and Systems Brown-bag Talks, UC Davis DataLab, May 28, 2021

De Loera(Math): Discrete Geometry Meeting, Mathematische Forschung Institut, Oberwolfach, Germany, Sep. 2020
Combinatorics Seminar, Univ. Washington, Oct. 2020
H.B. Keller Colloquium in Applied Mathematics, Caltech, Nov. 2020
Bay Area Discrete Mathematics Day (20th anniversary celebration), Nov. 2020
Colloquium of the Mexican Mathematical Society (in Spanish), Dec. 2020
AMS Special Session on Applied Combinatorial Methods, Joint Mathematics Meetings,Jan. 2021
Pi Mu Epsilon Conference, The College of Saint Benedict and Saint John's Univ., Apr. 2021
National Mathematics Festival (with more than 300 audience members including many high-school students), Apr. 2021
Colloquium, San Francisco State Univ., May 2021
The 18th Mixed Integer Programming Workshop (MIP), May 2021
Plenary speaker, SIAM Annual Meeting, Jul. 2021

Devanbu(CS): Keynote & Outstanding Award Lecture, International Conference on Software Engineering, Madrid, Spain, May 2021

Ding(ECE): Keynote talk, IEEE/CIC International Conference on Communications, Aug. 2020.
Mathematics of Data & Decisions at Davis (MADDD) Seminar, UC Davis, Nov. 2020.
IEEE Globecom Workshop on Advanced Technology for 5G Plus, Dec. 2020
IEEE ICC 2nd Workshop on Edge Learning for 5G Mobile Networks and Beyond, Jun. 2021

Drake(Stat): International Society for Clinical Biostatistics, Aug. 2020
The Fourteenth Workshop on Nonstationary Systems and Their Applications, Feb. 2021

Ghiasi(ECE): Mech. Eng. Seminar, UC Davis, Nov. 2020
UC Davis Medical Center Machine Learning Working Group, Mar. 2021
CeDAR annual meeting, May 2021
California State Summer School for Mathematics and Science (COSMOS) – outreach to high school audience, Jul. 2021
IEEE 17th International Conference on Wearable and Implantable Body Sensor Networks, Jul. 2021

Jiang(Stat): Annual Meeting of the Statistical Society of Canada, Jun. 2021

Koehl(CS): MADDD Seminar, Dept. Math, UC Davis, Oct. 2020

Koeppe(Math): Global Virtual SageDays 110, an event for the SageMath user and developer community, Oct. 2020
Global Virtual Sage Modularization and Packaging Summit, Dec. 2020

Le(Stat): VinAI, Nov. 2020

T.Lee(Stat): Joint Statistical Meetings, Aug. 2021

Y.J.Lee(CS): Keynote talk, OpenMMLab Tutorial, CVPR, Jun. 2021
AI Summer School, Seoul National Univ., Aug. 2020

Li(Stat): Computational and Methodological Statistics (CMStatistics), Dec. 2020
Eastern North American Region (ENAR) Statistics Conference, Mar. 2021
International Indian Statistical Association (IISA) Conference, May 2021

Lopes(Stat): Eastern North American Region (ENAR) Statistics Conference, Mar. 2021
Stat. Department Seminar, Univ. Illinois at Urbana-Champaign, Jan. 2021
Stat. Department Seminar, Rutgers Univ., Jan. 2021
DOE RASC Workshop, tutorial on Randomized Algorithms, Dec. 2020
Computational and Methodological Statistics (CMStatistics), Dec. 2020

Ma(Math): Online Seminar, Dept. Math, Nanjing Univ. of Science and Technology, Jul. 2021
SIAM Conference on Optimization, Jul. 2021
Two presentations at ICML, Jul. 2021
Mini-Symposium on Low-Rank Models and Applications, Fields Institute, Toronto, Canada. Jun. 2021
Workshop on Optimization Theory and Methods, Beijing International Center for Mathematical Research, Peking Univ., China. Jan. 2021
Seminar, Dept. Math, Sichuan Univ., China. Jan. 2021

Paul(Stat): EcoSta 2021, Hong Kong Univ. of Science and Technology, Jun. 2021
Seminar, Indian Statistical Institute, Jul. 2021

Polonik(Stat): MADDD Seminar, Nov. 2020

Rademacher(Math): Graduate Group in Applied Mathematics (GGAM) Mini Conference, UC Davis, Feb. 2021

Saito(Math): Japan SIAM Annual Meeting, Sep. 2020

Two lectures at Time-Frequency Frames and Applications to Image Processing, RIMS, Kyoto, Japan
Data Science Seminar, IMA/Univ. Minnesota, Nov. 2020
Colloquium, Dept. Comput. Math., Sci, & Eng., Michigan State Univ., Dec. 2020
Two talks at HSI Strategic Innovation Summit Series for Advanced Research and Instruction in AI & Quantum Information Sciences, UC Davis, Jun. 2021

Sharpnack(Stat): Chicago Booth ESC Workshop Seminar, Oct. 2020
Columbia Univ. Statistics Department Seminar, Mar. 2021
Berkeley/Davis Joint Statistics Colloquium, Apr. 2021

Vazquez(Math/MCB): Cibercoloquio Latinoamericano de Matemáticas, 06/19/2020
Math Biology Seminar, UC Davis 10/5/2020
Colloquium in honor of Hispanic Heritage Month, Univ. Alabama, 10/6/2020
Math Biology Seminar, Univ. Minnesota, 11/2/2020

Postdocs:
Roy(Stat): MADDD Seminar, UC Davis, Oct. 2020
NeurIPS (poster presentation), Dec. 2020
Canadian Operational Research Society (CORS), Jun. 2021

Schonsheck(Math): MADDD Seminar, UC Davis, Sep. 2020

Wang(ECE): MADDD Seminar, UC Davis, Oct. 2020
Machine Learning Working Group, UC Davis Health, Oct. 2020
Frontiers in Biomedical Imaging Seminar Series, UC Davis, Nov. 2020

Graduate Students:
Haydari(ECE): IEEE Vehicular Technology Conference, Apr. 2021

Jaramillo-Rodriguez(Math): Student Run Research Seminar, Dept. Math, UC Davis, Apr. 2021

Vali(ECE): Society for Maternal-Fetal Medicine Conference, Feb. 2021

Xu(Stat): Topics in Astrostatistics Seminar, International CHASC AstroStatistics Centre, Feb. 2021

Dissemination effort other than talks:
Saito(Math) has created the GitHub repository for any UCD4IDS members, which currently lists nine open-source software packages.

Koeppe(Math) has become the lead developer of SageMath, an open source mathematical system whose importance in data science research is rising.

Weber(Math; Graduate Student) developed and disseminated his FourierFilterFlux.jl Julia package, which allows for GPU and CPU based Fourier transform computation and auto-differentiation of filtering operations. The details are listed in our Products section.

*** What do you plan to do during the next reporting period to accomplish the goals?**

We will plan to have more in-person seminars, meetings, and roundtable discussions in the forthcoming year to make further progress on every front of research, teaching, and training of our graduate students. In addition, we plan to organize a workshop in Fall 2022 and use the external evaluation on our progress provided by the Resources on Excellence in Education (REEd) program within the UC Davis School of Education. REEd has provided evaluation services to a number of NSF grants on the UC Davis campus.

Products

Books

Jiang, J.; Nguyen, T. (2021). *Linear and Generalized Linear Mixed Models and Their Applications, 2nd.* Springer. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: https://doi.org/10.1007/978-1-0716-1282-8

Book Chapters

Strohmer, T.; Wertz, T. (2021). Almost eigenvalues and eigenvectors for almost Mathieu operators. *Applied and Numerical Harmonic Analysis: In Honor of John Benedetto's 80th Birthday* Springer. . Status = AWAITING_PUBLICATION; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes ; DOI:

Wang, C.; Chan, R. H.; Plemmons, R. J.; Prasad, S. (2021). Point spread function engineering for 3D imaging using a continuous exact L0 penalty (CEL0) based algorithm. *Mathematical Methods in Image Processing and Inverse Problems* Springer. . Status = ACCEPTED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes

Inventions

Journals or Juried Conference Papers

View all journal publications currently available in the NSF Public Access Repository for this award.

The results in the NSF Public Access Repository will include a comprehensive listing of all journal publications recorded to date that are associated with this award.

Schonsheck, Stefan C. and Bronstein, Michael M. and Lai, Rongjie. (2021). Nonisometric Surface Registration via Conformal Laplace–Beltrami Basis Pursuit. *Journal of Scientific Computing*. 86 (3) . Status = Deposited in NSF-PAR doi:https://doi.org/10.1007/s10915-020-01390-y ; Federal Government's License = Acknowledged. (Completed by Saito, null on 08/03/2021) Full text Citation details

Liu, Zhenyu and Zhang, Lin and Ding, Zhi. (2020). Overcoming the Channel Estimation Barrier in Massive MIMO Communication via Deep Learning. *IEEE Wireless Communications*. 27 (5) 104 to 111. Status = Deposited in NSF-PAR doi:https://doi.org/10.1109/MWC.001.1900413 ; Federal Government's License = Acknowledged. (Completed by Saito, null on 08/02/2021) Full text Citation details

McNulty, Matthew J. and Kelada, Kirolos and Paul, Debashis and Nandi, Somen and McDonald, Karen A.. (2021). Introducing uncertainty quantification to techno-economic models of manufacturing field-grown plant-made products. *Food and Bioproducts Processing*. 128 (C) 153 to 165. Status = Deposited in NSF-PAR doi:https://doi.org/10.1016/j.fbp.2021.04.013 ; Federal Government's License = Acknowledged. (Completed by Saito, null on 08/02/2021) Full text Citation details

Koehl, Patrice and Delarue, Marc and Orland, Henri. (2021). Simultaneous Identification of Multiple Binding Sites in Proteins: A Statistical Mechanics Approach. *The Journal of Physical Chemistry B*. 125 (19) 5052 to 5067. Status = Deposited in NSF-PAR doi:https://doi.org/10.1021/acs.jpcb.1c02658 ; Federal Government's License = Acknowledged. (Completed by Saito, null on 08/02/2021) Full text Citation details

Wu, Ping and Jiang, Jiming. (2021). Robust estimation of mean squared prediction error in small-area estimation. *Canadian Journal of Statistics*. 49 (2) 362 to 396. Status = Deposited in NSF-PAR doi:https://doi.org/10.1002/cjs.11567 ; Federal Government's License = Acknowledged. (Completed by Saito, null on 08/04/2021) Full text Citation details

Wang, Chao and Tao, Min and Nagy, James G. and Lou, Yifei. (2021). Limited-Angle CT Reconstruction via the L_1/L_2 Minimization. *SIAM Journal on Imaging Sciences*. 14 (2) 749 to 777. Status = Deposited in NSF-PAR doi:https://doi.org/10.1137/20M1341490 ; Federal Government's License = Acknowledged. (Completed by Saito, null on 08/03/2021) Full text Citation details

Tatro, N. J. and Schonsheck, S. C. and Lai, R.. (2021). Unsupervised Geometric Disentanglement via CFAN-VAE. *ICLR 2021 Workshop on Geometrical and Topological Representation Learning*. . Status = Deposited in NSF-PAR Federal Government's License = Acknowledged. (Completed by Saito, null on 08/03/2021) Full text Citation details

Jiang, Jiming and Feuer, Eric J and Li, Yuanyuan and Nguyen, Thuan and Yu, Mandi. (2021). Inference about age-standardized rates with sampling errors in the denominators. *Statistical Methods in Medical Research*. 30 (2) 535 to 548. Status = Deposited in NSF-PAR doi:https://doi.org/10.1177/0962280220962516 ; Federal Government's License = Acknowledged. (Completed by Saito, null on 08/04/2021) Full text Citation details

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Ma, S.; Hong, M. (2021). *A Gentle Introduction to ADMM for Statistical Problems*. Wiley StatsRef: Statistics Reference Online https://doi.org/10.1002/9781118445112.stat08314. Status = PUBLISHED; Acknowledgement of Federal Support = No

Patent Applications

Contextually aware fetal sensing in transabdominal fetal pulse oximetry . Patent No. US16/820,388 . UNITED STATES. Application Date = 03/16/2020 . Status = Pending

Technologies or Techniques

Thesis/Dissertations

Chen, Ji. *Nonconvex Matrix Completion: From Geometric Analysis to Algorithmic Analysis*. (2020). UC Davis.

Acknowledgement of Federal Support = Yes

Roy, Abhishek. *On Online Nonconvex Nonstationary Optimization and Game Theory*. (2020). UC Davis.
Acknowledgement of Federal Support = No

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A Basic Guide for Package Development in Julia
https://github.com/ShozenD/julia-pkg-dev

Julia package development tutorial, in particular, discussing how to ***simultaneously*** manage and maintain one's Julia package on both GitHub.com and GitLab.com

Contributions to SageMath version 9.2 in the form of 171 peer-reviewed change tickets for multilinear algebra, build/configuration system, refactoring, documentation, continuous integration
https://www.sagemath.org/changelogs/sage-9.2.txt

Matthias Koeppe, Contributions to SageMath version 9.2 in the form of 171 peer-reviewed change tickets for multilinear algebra, build/configuration system, refactoring, documentation, continuous integration, listed at https://www.sagemath.org/changelogs/sage-9.2.txt, October 2020.

Contributions to SageMath version 9.3 in the form of 182 peer-reviewed change tickets for the build/configuration system, refactoring, documentation, continuous integration
https://www.sagemath.org/changelogs/sage-9.3.txt

Matthias Koeppe, Contributions to SageMath version 9.3 in the form of 182 peer-reviewed change tickets for the build/configuration system, refactoring, documentation, continuous integration, listed at https://www.sagemath.org/changelogs/sage-9.3.txt, May 2021.

GitHub Organizations & GitLab Groups Tutorial
https://github.com/zengfung/git-organization-tutorial

Brief and quick tutorial on how to set up and navigate organizations in GitHub and GitLab

LDBExperiments
https://github.com/ShozenD/LDBExperiments

Tutorials and experiments using **Local Discriminant Basis (LDB)**. In this Pluto notebook we describe the algorithm behind LDB and test its classification capabilities by applying it on two standard signal classification datasets.

MultiscaleGraphSignalTransforms.jl
https://github.com/UCD4IDS/MultiscaleGraphSignalTransforms.jl

MultiscaleGraphSignalTransforms.jl is a collection of software tools written in the Julia programming language for graph signal processing including HGLET, GHWT, eGHWT, NGWP, Lapped NGWP, and Lapped HGLET. Some of them were originally written in MATLAB by Jeff Irion, but we added more functionalities, e.g., eGHWT, NGWP, etc.

UC Davis TETRAPODS Institute of Data Science (UCD4IDS)
https://github.com/UCD4IDS

GitHub Organization of the UCD4IDS members and associates for open software repository.

WaveletsDenoisingExperiment
https://github.com/UCD4IDS/WaveletsDenoisingExperiment

A Pluto notebook to demonstrate the power of wavelets and wavelet packets for signal denoising.

WaveletsExt.jl
https://github.com/UCD4IDS/WaveletsExt.jl

This package is a Julia extension package to Wavelets.jl (WaveletsExt is short for Wavelets Extension). It contains additional functionalities that complement Wavelets.jl, which include multiple best basis algorithms, denoising methods, Local Discriminant Basis (LDB), Stationary Wavelet Transform, Autocorrelation Wavelet Transform (ACWT), and the Shift Invariant Wavelet Decomposition.

cutgeneratingfunctionology: Python code for computation and experimentation with cut-generating functions
https://github.com/mkoeppe/cutgeneratingfunctionology

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Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Saito, Naoki	PD/PI	4
Amenta, Annamaria	Co PD/PI	1
Chuah, Chen-Nee	Co PD/PI	1
Lee, Thomas Chun Man	Co PD/PI	1
Arsuaga, Javier	Faculty	1
Aue, Alexander	Faculty	1
Balasubramanian, Krishna	Faculty	1
Burman, Prabir	Faculty	0
Chaudhuri, Rishidev	Faculty	1
Chen, Shizhe	Faculty	1
De Loera, Jesus	Faculty	1
Devanbu, Premkumar	Faculty	1
Ding, Zhi	Faculty	1
Drake, Christiana	Faculty	1
Fannjiang, Albert	Faculty	4
Ghiasi, Soheil	Faculty	1

Name	Most Senior Project Role	Nearest Person Month Worked
Hass, Joel	Faculty	0
Hsieh, Fushing	Faculty	1
Jiang, Jiming	Faculty	0
Koehl, Patrice	Faculty	1
Koeppe, Matthias	Faculty	1
Lai, Lifen	Faculty	1
Le, Can	Faculty	1
Lee, Yong Jae	Faculty	1
Li, Xiaodong	Faculty	1
Lopes, Miles	Faculty	1
Ma, Shiqian	Faculty	1
Paul, Debashis	Faculty	1
Polonik, Wolfgang	Faculty	1
Rademacher, Luis	Faculty	1
Rajaratnam, Balakanapathy	Faculty	1
Sharpnack, James	Faculty	1
Strohmer, Thomas	Faculty	2
Tagkopoulos, Ilias	Faculty	1
Vazquez, Mariel	Faculty	1
Roy, Abhishek	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Schonsheck, Stefan	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Wang, Chao	Postdoctoral (scholar, fellow or other postdoctoral position)	12

Name	Most Senior Project Role	Nearest Person Month Worked
Blandino, Andrew	Graduate Student (research assistant)	2
Feng, Xue	Graduate Student (research assistant)	2
Haydari, Ammar	Graduate Student (research assistant)	2
He, Ye	Graduate Student (research assistant)	1
Hu, Rui	Graduate Student (research assistant)	1
Huang, Yishan	Graduate Student (research assistant)	1
Jaramillo-Rodriguez, Edgar	Graduate Student (research assistant)	2
Kim, Tae	Graduate Student (research assistant)	1
Kumar, Girish	Graduate Student (research assistant)	1
Lai, Zhengfeng	Graduate Student (research assistant)	2
Leroux, Brett	Graduate Student (research assistant)	1
Li, Jiaxiang	Graduate Student (research assistant)	1
Li, Tianke	Graduate Student (research assistant)	1
Liu, Yucheng	Graduate Student (research assistant)	1
Ni, Yuan	Graduate Student (research assistant)	1
Shvarts, Eugen	Graduate Student (research assistant)	1
Vali, Kourosh	Graduate Student (research assistant)	2
Wan, Qianhui	Graduate Student (research assistant)	1
Wang, Jue	Graduate Student (research assistant)	1
Weber, David	Graduate Student (research assistant)	1
Wei, Zhenyu	Graduate Student (research assistant)	2
Xiao, Tesi	Graduate Student (research assistant)	1
Xu, Cong	Graduate Student (research assistant)	2

Name	Most Senior Project Role	Nearest Person Month Worked
Zhang, Zhenyang	Graduate Student (research assistant)	1

Full details of individuals who have worked on the project:

Naoki Saito
Email: saito@math.ucdavis.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 4

Contribution to the Project: Coordinated and managed almost all the activities of the UCD4IDS; Organized the Mathematics of Data and Decision seminar series, video recorded all but one talk, and put the video files and the talk slides on the publicly available website (Fall 2020); Managed and maintained the dedicated UCD4IDS website; Conducted research; supervised one Ph.D. student; gave presentations on our research and projects at various conferences and seminars.

Funding Support: NSF Grant DMS-1912747; NSF Grant IIS-1631329; NSF RTG Grant DMS-1148643; ONR Grant N00014-20-1-2381; UC Davis CeDAR Seed Grant

Change in active other support: No

International Collaboration: No
International Travel: No

Annamaria B Amenta
Email: amenta@cs.ucdavis.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; participated in the roundtable discussions

Funding Support: None

Change in active other support: No

International Collaboration: No
International Travel: No

Chen-Nee Chuah
Email: chuah@ucdavis.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised postdocs and graduate students; attended seminars; participated in the roundtable discussions; served as a member of the Steering Committee.

Funding Support: NIH grant 1R21HD099239-01; DoD CDMRP grant #W81XWH1820072.

Change in active other support: No

International Collaboration: No
International Travel: No

Thomas Chun Man Lee
Email: tcmlee@ucdavis.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; served as a member of the Steering Committee.

Funding Support: None

Change in active other support: No

International Collaboration: No
International Travel: No

Javier Arsuaga
Email: jarsuaga@math.ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Ensured the integrity of the research; mentored students and researchers; prepared manuscripts; worked on some experiments required for the COVID-19 project.

Funding Support: NSF grants: DMS-1854770; DMS-2030491 UC Davis CeDar seed grant.

International Collaboration: No
International Travel: No

Alexander Aue
Email: aaue@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; participated in the roundtable discussions; served as a member of the Steering Committee

Funding Support: California DPR grant 15-C0055

International Collaboration: No
International Travel: No

Krishna Balasubramanian
Email: kbala@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; participated in the roundtable discussions.

Funding Support: UC Davis CeDAR Innovative Data Science Seed Funding Program

International Collaboration: No
International Travel: No

Prabir Burman
Email: pburman@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 0

Contribution to the Project: Conducted research; co-supervised a graduate student in Biostatistics (Maxime Pouokam); attended seminars; participated in the roundtable discussions

Funding Support: None

International Collaboration: No
International Travel: No

Rishidev Chaudhuri
Email: rchaudhuri@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; participated in the roundtable discussions; gave talks; wrote papers

Funding Support: UC Davis New Faculty Startup Funds

International Collaboration: No
International Travel: No

Shizhe Chen
Email: szdchen@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars

Funding Support: NSF DMS-1916476

International Collaboration: No
International Travel: No

Jesus De Loera
Email: deloera@math.ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised 2 graduate students involved with grant; attended seminars; participated in the roundtable discussions, coordinated the funding of all Math/Applied math students involved; served as a member of the Steering Committee.

Funding Support: NSF DMS-1818969

International Collaboration: No
International Travel: No

Premkumar Devanbu
Email: ptdevanbu@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Presented a tutorial to the TRIPODS group on the use Containeraization for reproducible data analysis. Tutorial was based on material previously developed for undergraduate software engineering class, but was customized to be useful for researchers outside CS discipline, to be more of a "live coding" experience.

Funding Support: NSF grants: 1414172; 1840191; 2016735.

International Collaboration: No
International Travel: No

Zhi Ding
Email: zding@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Planning research directions; supervising graduate student researchers; Taking part in seminars; gave a MADDD seminar talk; participating in discussions; served as a member of the Steering Committee

Funding Support: NSF grants: 1711823, 1824553.

International Collaboration: No
International Travel: No

Christiana Drake
Email: cmdrake@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars

Funding Support: CA Dept. Transportation grant 65A0686; US Dept. Veterans Affairs grant 1BX004423-01A1

International Collaboration: No
International Travel: No

Albert Fannjiang
Email: fannjiang@math.ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 4

Contribution to the Project: Conducted research; supervised graduate students; attended seminars.

Funding Support: Simons Foundation Grant FDN 2019-24

International Collaboration: Yes, Taiwan
International Travel: No

Soheil Ghiasi
Email: ghiasi@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; participated in the roundtable discussions

Funding Support: NSF grants IIS-1838939 & CBET-1937158; NIH grant R21HD097467-A1; UC Davis CeDAR Innovative Data Science Seed Funding Program

International Collaboration: No
International Travel: No

Joel Hass
Email: hass@math.ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 0

Contribution to the Project: Conducted research; attended seminars; participated in roundtable discussions

Funding Support: NSF DMS-1719582 & DMS-1760485

International Collaboration: No
International Travel: No

Fushing Hsieh
Email: fhsieh@ucdavis.edu
Most Senior Project Role: Faculty

Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; organized Statistics Seminar series (Fall 2020).

Funding Support: UC Davis CeDAR Innovative Data Science Seed Funding Program

International Collaboration: No
International Travel: No

Jiming Jiang
Email: jimjiang@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 0

Contribution to the Project: Conducting research; Supervising graduate students; Attended seminars

Funding Support: None

International Collaboration: No
International Travel: No

Patrice Koehl
Email: pakoehl@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; gave a MADDD seminar talk; served as a member of the Steering Committee

Funding Support: NSF grant DMS-1760485

International Collaboration: No
International Travel: No

Matthias Koeppe
Email: mkoeppe@math.ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; developed software; organized a weekly MADDD seminar (Winter 2021); curated a weekly selection of international online research seminars (Winter/Spring quarters)

Funding Support: NSF DMS-2012764

International Collaboration: No
International Travel: No

Lifen Lai
Email: lflai@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; participated in the roundtable discussions

Funding Support: None

International Collaboration: No
International Travel: No

Can Le
Email: canle@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; participated in the roundtable discussions

Funding Support: NSF grant DMS-2015134

International Collaboration: No
International Travel: No

Yong Jae Lee
Email: yongjaelee@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students;

Funding Support: NSF IIS-1751206

International Collaboration: No
International Travel: No

Xiaodong Li
Email: xdgli@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; participated in the roundtable discussions; give talks on these projects.

Funding Support: NSF DMS-1848575

International Collaboration: Yes, Hong Kong
International Travel: No

Miles Lopes
Email: melopes@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars.

Funding Support: NSF grant: DMS-1915786

International Collaboration: No
International Travel: No

Shiqian Ma
Email: sqma@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; presented works in conferences.

Funding Support: NSF grantsDMS-1953210 & CCF-2007797; UC Davis CeDAR Innovative Data Science Seed Funding Program

International Collaboration: Yes, Hong Kong
International Travel: No

Debashis Paul
Email: debpaul@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students (Tongyi Tang, supported through the TRIPODS grant); attended seminars.

Funding Support: NSF grants DMS-1713120, DMS-1811405 and DMS-1915894

International Collaboration: Yes, Italy, United Kingdom
International Travel: No

Wolfgang Polonik
Email: wpolonik@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Luis Rademacher
Email: lrademac@math.ucdavis.edu

Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; participated in the roundtable discussions

Funding Support: NSF CCF-2006994

International Collaboration: No
International Travel: No

Balakanapathy Rajaratnam
Email: brajaratnam@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; upervised graduate students; attended seminars; involved in curriculum development.

Funding Support: NSF DMS-1916787

International Collaboration: No
International Travel: No

James Sharpnack
Email: jsharpna@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars

Funding Support: NSF DMS-1712996

International Collaboration: No
International Travel: No

Thomas Strohmer
Email: strohmer@math.ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2

Contribution to the Project: Conducted research; supervised graduate students; attended seminars; organized the Joint Mathematics-Statistics Colloquium (Spring 2021)

Funding Support: NSF-DMS-1737943 and NSF-DMS-2027248; UC Davis CeDAR Innovative Data Science Seed Funding Program

International Collaboration: No
International Travel: No

Ilias Tagkopoulos
Email: itagkopoulos@ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised graduate students; attended seminars.

Funding Support: NSF/USDA/NIH grants

International Collaboration: No
International Travel: No

Mariel Vazquez
Email: mariel@math.ucdavis.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; supervised undergraduate andgraduate students; organized Math Bio seminar and attended some meetings of the MADDD seminar; participated in some roundtable discussions.

Funding Support: NSF DMS-2030491; DMS-1817156; DMS-1716987; the UC Davis CeDAR Seed Grant

International Collaboration: No
International Travel: No

Abhishek Roy
Email: abroy@ucdavis.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12

Contribution to the Project: Conducted research; attended seminars; presented papers at conference; gave talks.

Funding Support: Partial support from the College of Letters & Science Dean's office

International Collaboration: No
International Travel: No

Stefan C. Schonsheck
Email: scschonsheck@ucdavis.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12

Contribution to the Project: Conducted research: Stability of geometric convolutions, geometric normal flows, Chart-based parameterization of data. Organized Mathematics of Data and Decision at Davis (MADDD) seminar series (Spring 2021). Constantly attended One World IMAGINE seminar seris.

Funding Support: Partially supported by the A. J. Krener Assistant Professorship, Department of Mathematics, UC Davis

International Collaboration: No
International Travel: No

Chao Wang
Email: ecewang@ucdavis.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12

Contribution to the Project: Conducted research; supervised graduate students; organized interdisciplinary AI + Biomedical imaging seminar series

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Funding Support: None

International Collaboration: No
International Travel: No

Andrew Blandino
Email: ablandino@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Xue Feng
Email: xffeng@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Conducted research; attended seminars.

Funding Support: NSF-DMS-1737943 and NSF-DMS-2027248

International Collaboration: No
International Travel: No

Ammar Haydari
Email: ahaydari@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Ye He
Email: leohe@math.ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Rui Hu
Email: rhhu@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Yishan Huang
Email: yishuang@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars

Funding Support: None

International Collaboration: No
International Travel: No

Edgar Jaramillo-Rodriguez
Email: edgarjr@math.ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Conducted research; attended seminars

Funding Support: None

International Collaboration: Yes, Germany, Mexico
International Travel: No

Tae Yen Kim
Email: atykim@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Girish Kumar
Email: gkum@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research and learned theory; attended seminars.

Funding Support: NSF-DMS-1737943 and NSF-DMS-2027248

International Collaboration: No
International Travel: No

Zhengfeng Lai
Email: lzhengfeng@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Brett Leroux
Email: leroux@math.ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars.

Funding Support: NSF CCF 2006994

International Collaboration: No
International Travel: No

Jiaxiang Li
Email: jasonljx@math.ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Tianke Li
Email: tkli@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Yucheng Liu
Email: yucliu@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Yuan Ni
Email: yuani@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Eugen Shvarts
Email: eshvarts@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Kourosh Vali
Email: kvali@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Conducted research; attended seminars; participated in roundtable discussions

Funding Support: NSF grants IIS-1838939 & CBET-1937158; NIH grant R21HD097467-A1; UC Davis CeDAR Innovative Data Science Seed Funding Program

International Collaboration: No
International Travel: No

Qianhui Wan
Email: qhswan@math.ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars; participated in roundtable discussions

Funding Support: None

International Collaboration: No
International Travel: No

Jue Wang
Email: jujwang@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars; led meetings; drafted a paper.

Funding Support: None

International Collaboration: Yes, Greece
International Travel: No

David Weber
Email: dsweber@math.ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars; participated in roundtable discussions; served as a scribe for roundtable discussions; helped PI to maintain the project website.

Funding Support: ONR grant N00014-20-1-2381

International Collaboration: No
International Travel: No

Zhenyu Wei
Email: zywei@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Tesi Xiao
Email: texiao@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars; participated in roundtable discussions

Funding Support: None

International Collaboration: No
International Travel: No

Cong Xu
Email: cngxu@ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 2

Contribution to the Project: Conducted research; attended seminars.

Funding Support: None

International Collaboration: No
International Travel: No

Zhenyang Zhang
Email: zhenyangz@math.ucdavis.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Conducted research; attended seminars.

Funding Support: NSF DMS-181896

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?
Nothing to report.

Were other collaborators or contacts involved? If so, please provide details.
Nothing to report

Impacts

What is the impact on the development of the principal discipline(s) of the project?

The theory, algorithms, and software tools that have been and are being developed will be likely to make a positive impact in solving practical data-analysis and machine-learning problems in our core disciplines, i.e., computer science (analyzing social networks and website links); electrical engineering (monitoring and controlling sensor networks); mathematics

(nonconvex optimization theory and algorithms; data analysis on hypergraphs); and statistics (inverse problems, statistical graph and network analysis).

What is the impact on other disciplines?

Our research and development above will also be likely to make a positive impact on other disciplines, e.g., civil engineering (monitoring traffic flow on a road network); biology and medicine (analyzing data measured on real neural networks, detecting changes in the brain structures due to diseases, imaging live biological cells for analyzing their growth, real-time monitoring of health of fetuses); agriculture and veterinary medicine (monitoring and improving milk reproduction management), etc.

What is the impact on the development of human resources?

Through this project, many of our students have become familiar with data obtained from scientists in the different fields such as neuroscience, biomedical engineering, medicine, environmental sciences, and anthropology, etc. Also, through the weekly Mathematics of Data and Decision at Davis (MADDD) seminars, the weekly Statistics seminars, and the annual Joint Mathematics/Statistics Colloquia, students in each of our four departments had opportunities to get to know the students from the other three departments better. In addition, they had opportunities to meet and discuss with invited speakers from industry to hear their experience in industry and what kind of knowledge and skills are expected in industry. Finally, through the interdisciplinary UC Davis internal seed grants provided by the Center for Data Science and Artificial Intelligence Research (CeDAR), some of our students actually collaborated on research projects beyond the departmental boundaries.

What was the impact on teaching and educational experiences?

Our research activities and interdisciplinary collaboration efforts in data science and machine learning have certainly influenced the creation of the two graduate courses during this review period we mentioned in the Training and Professional Development section of this report:

- *MAT 270: Mathematical Foundation of Data Science*
- *STA 208: Statistical Methods in Machine Learning*

In addition, we believe that we, as a group of 35 faculty members, have influenced on the major decision of our campus: we are offering **Data Science Undergraduate Major** degrees starting Fall 2022! The curriculum for this DS major degree will be organized into four initial tracks:

1. Foundations;
2. Agricultural and Environmental Sciences;
3. Biological Sciences; and
4. Social Sciences.

Then, majors in every track will receive ethics training as well as some foundational courses in CS, Math, and Stat, e.g., MAT 19 sequence (Calculus for Data-Driven Applications). Our predicted enrollment after two years is about 600 majors, which is an impressive number.

What is the impact on physical resources that form infrastructure?

The project will contribute the campus-wide High Performance Computing (HPC) Core Facility for their GPU purchase. As we reported in the Major Activities section, 26 members of the UCD4IDS created their CPU/GPU cluster accounts at the HPC Core Facility, and started running their jobs on the currently available GPUs.

What is the impact on institutional resources that form infrastructure?

UC Davis administration has allocated space for our activities in the first and ground floors of the Physical Sciences and Engineering Library. Currently, the building renovation is underway for this purpose with the planned completion date of December 2022.

What is the impact on information resources that form infrastructure?
Nothing to report.

What is the impact on technology transfer?
Nothing to report.

What is the impact on society beyond science and technology?
Nothing to report.

What percentage of the award's budget was spent in a foreign country?
Nothing to report.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.

Change in primary performance site location
Nothing to report.