GREGORY CANAL

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RESEARCH INTERESTS

The objective of my research is to develop and analyze foundational machine learning models and algorithms. I am particularly interested in the design of systems that **actively learn from data** by intelligently selecting a minimal set of measurements or data labels, and processing them in a computationally efficient manner. Such systems are especially important in human-in-the-loop settings, where both the number of requested labels and the latency (i.e., computational cost) between each label request must be minimized. I typically approach my research using concepts from information theory, adaptive sensing, low-dimensional and generative modeling, and Bayesian statistics, among other tools. I have worked on collaborative projects in problem domains such as active learning and adaptive localization, comparison-based metric and preference learning, image segmentation, brain-computer interfacing, explainable artificial intelligence, and deep generative modeling, and have published my results in multiple top-tier machine learning conferences.

EDUCATION

Ph.D. in Electrical and Computer Engineering   August 2015 – August 2021
Georgia Institute of Technology
   Dissertation: Feedback Coding for Efficient Interactive Machine Learning
   Advisor: Dr. Christopher Rozell

M.S. in Electrical and Computer Engineering   August 2015 – December 2017
Georgia Institute of Technology

B.S.E. in Electrical and Computer Engineering, Minor in Music   August 2011 – May 2015
Duke University (*Summa Cum Laude*)
   Senior Thesis: Visual Search Using Event-Related Potentials in a Brain-Computer Interface
   Advisor: Dr. Leslie Collins

WORK EXPERIENCE

Senior AI Research Scientist   2023 – Present
Johns Hopkins University Applied Physics Laboratory   *Laurel, MD*

Postdoctoral Research Associate   2021 – 2023
Wisconsin Institute for Discovery, University of Wisconsin-Madison   *Madison, WI*
Postdoc Advisor: Dr. Robert Nowak
   - Developed and analyzed convex algorithms for simultaneous metric and preference learning in a multi-user comparison-based recommender system, in collaboration with another postdoctoral researcher
   - Theoretically proved the significant increase in query efficiency gained by modeling shared structure across users, and empirically validated the proposed algorithms on a color preferences task
   - Frequent prototyping, algorithm development, and experiment execution in Python 3 using libraries including PyTorch, Scikit-learn, SciPy, NumPy, CVXPY, Pandas, Matplotlib, Seaborn

Graduate Research Assistant   2016 – 2021
Georgia Institute of Technology   *Atlanta, GA*
   - Formulated active learning as a feedback coding problem to develop a novel example selection algorithm, theoretically analyzed its use in logistic regression, and empirically demonstrated (in Python) the algorithm's reduced label cost and order of magnitude computational speed-up when compared to existing selection methods on real-world datasets
   - Developed and analyzed new algorithms for rapidly estimating a user's preferences in a recommender system by adaptively querying paired comparisons between items, and demonstrated significant accuracy and compute cost improvements over state-of-the-art methods in Python simulations

- Designed and implemented an efficient sampling strategy for learning ordinal embeddings by using a novel high-order ordinal query type, and demonstrated improved performance over baseline active ordinal embedding methods on simulated and newly collected human datasets
- Developed a brain-computer interface that utilizes an optimal feedback coding scheme to efficiently control a robotic swarm through the extraction and classification of EEG features with filtering and machine learning techniques (in MATLAB), achieving an accuracy of 75% correct swarm configurations over 70 trials of a single subject and verifying system usability via Amazon Mechanical Turk
- Collaborated with other Ph.D. students to develop novel deep generative models for a causality-based explainable artificial intelligence system and a variational inference method based on manifold learning

Intern   Summer 2017
LGS Innovations (now CACI)   *Florham Park, NJ*
- Developed and analyzed signal models and source separation solutions for multiple-input multiple-output digital communications systems, including a novel problem-specific extension of independent component analysis which was subsequently integrated into a deployed customer system
- Successfully demonstrated solution performance on both simulated and real-world customer datasets, fully documented methods and results in an internal report, and presented in a departmental seminar, resulting in the receipt of a selective "LGS STAR" internship award

Undergraduate Researcher - Pratt Fellows Research Program   2014 – 2015
Duke University   *Durham, NC*
- Designed and analyzed experiments investigating the use of a brain-computer interface for rapid visual searching of images by a human operator, as an alternative to point-and-click image searching
- Learned C++ to develop real-time experimental applications that measure scalp electrode data for subsequent signal processing and classification in MATLAB

Teaching and Mentoring Experience

Project Mentor - Empirical Metric and Preference Learning   2022 – 2023
Wisconsin Institute for Discovery, University of Wisconsin-Madison   *Madison, WI*
- Served as primary project mentor on an undergraduate student's senior honors thesis
- Guided the empirical evaluation of metric and preference learning algorithms on real-world datasets, with the goal of corroborating the algorithms' performance in practice

Project Mentor - Interactive Image Segmentation   2016 – 2018
Georgia Institute of Technology   *Atlanta, GA*
- Managed and mentored two undergraduate students on an image processing project applying optimal feedback coding to interactively specifying image segments using only one-bit inputs, applicable to hands-free human-computer interaction and assistive devices
- Demonstrated significant query savings (thereby reducing human interaction burden) compared to the state-of-the-art interaction algorithm, resulting in a conference publication

Graduate Teaching Assistant - Introduction to Signal Processing   Fall 2015
Georgia Institute of Technology, School of Electrical and Computer Engineering   *Atlanta, GA*
- Instructed undergraduate students in weekly laboratory sessions exploring fundamental signal processing concepts in MATLAB

Laboratory Teaching Assistant - Signals and Systems   Fall 2013, Fall 2014, Spring 2015
Duke University, Department of Electrical and Computer Engineering   *Durham, NC*
- Led weekly laboratory sessions that implemented signal processing concepts with MATLAB, Simulink, and data acquisition boards
- Served as head laboratory teaching assistant in spring 2015, with additional responsibilities consisting of coordinating with laboratory managers and faculty to plan exercises, and leading weekly meetings to prepare teaching assistants for each lab

Professional Activities and Service

Leadership

- **Founder and Discussion Leader**, Neural Collapse Reading Group,   Fall 2022
  University of Wisconsin-Madison
- **Organizer and Session Chair**, "Robustness in Deep Learning" mini-symposium at the   2022
  SIAM Conference on Mathematics of Data Science (MDS22), San Diego, CA
- **Organizer and Co-chair**, Systems, Information, Learning and Optimization (SILO)   2022
  seminar series, University of Wisconsin-Madison
- **Co-chair**, Institute for Foundations of Data Science (IFDS)   Fall 2021
  seminar series, University of Wisconsin-Madison
- **Organizer**, Atlanta Science Festival community outreach event on   2019
  Neuro-Engineering: Blurring the Lines Between Mind and Machine
- **Board Member**, Georgia Tech ECE Graduate Student Organization   2016 – 2019
  - Organized social and networking events for graduate students in the School of Electrical and Computer Engineering
  - Served as a student mentor for multiple incoming graduate students, providing advice and guidance on succeeding in coursework, research, and life as a Ph.D. student

Reviewer

- Conference on Neural Information Processing Systems (NeurIPS)   2021 (top 8% of reviewers), 2022
- International Conference on Machine Learning (ICML)   2022 (top 10% of reviewers)
- IEEE International Symposium on Information Theory (ISIT)   2022
- International Conference on Learning Representations (ICLR)   2022
- IEEE Journal on Selected Areas in Information Theory   2021
- International Conference on Artificial Intelligence and Statistics (AISTATS)   2021
- Signal Processing with Adaptive Sparse Structured Representations (SPARS)   2019

Volunteer Work

- **Student Technician**, Duke Engage / Engineering World Health, Tanzania   Summer 2013
  - Volunteered for a month as a hospital technician in partnership with another student, with duties including troubleshooting and repairing over 70 biomedical devices, creating and maintaining an inventory of over 200 devices and parts, and establishing a hospital engineering infrastructure

Workshops

- **Participant**, MADLab Summer Workshop, Chicago, IL. Lightning talk   June 2022
- **Selected Participant**, ComSciCon-Atlanta, Atlanta, GA   March 2020
- **Participant**, Information Theory and Applications (ITA) Workshop   February 2020
  University of California San Diego, San Diego, CA. Poster presentation
- **Selected Participant**, Career, Research, and Innovation Development Conference   February 2019
  (CRIDC), Georgia Institute of Technology, Atlanta, GA. Poster presentation
- **Selected Participant**, TRIPODS Summer School, Institute for Foundations of   July 2018
  Data Science, University of Wisconsin-Madison, Madison, WI. Poster presentation

Grants Contributed To

DARPA - Active Similarity Learning and Manifold Graphs for Learning with Few Labels   2019
- Assisted in the development of project objectives and co-authored multiple proposal sections

Honors and Awards

Fellowships and Scholarships
- IDEaS-TRIAD Research Scholarship 2020
- Georgia Tech President's Fellowship 2015
- Tau Beta Pi Fellowship 2015

Awards
- NeurIPS Outstanding Reviewer Award (top 8% of reviewers) 2021
- International BCI Meeting Student Award 2018
- LGS Innovations STAR Scholar Award 2017
- Outstanding Undergraduate Teaching Award 2015

Undergraduate Academic Honors
- Graduation with Departmental Distinction 2015
- Inducted to Phi Beta Kappa 2015
- Dean's List with Distinction / Dean's List 2011 − 2015
- Student Marshal 2014
- STEAM Challenge Honorable Mention 2014
- Inducted to Tau Beta Pi 2014
- Inducted to Eta Kappa Nu 2013
- Anne Marie Parsons Memorial Prize in Jazz Studies 2012

Publications

Journal-style, Refereed, Conference Publications

1. H. Bai, **G. Canal**, X. Du, J. Kwon, R. Nowak, and Y. Li. Feed two birds with one scone: exploiting wild data for both out-of-distribution generalization and detection. In *The 40th International Conference on Machine Learning (**ICML**)*, Honolulu, HI, July 2023. (Acceptance rate 28%).

2. **G. Canal**, B. Mason, R. K. Vinayak, and R. Nowak. One for all: simultaneous metric and preference learning over multiple users. In *The 36th Conference on Neural Information Processing Systems (**NeurIPS**)*, New Orleans, LA, December 2022. (Acceptance rate 26%).

3. **G. Canal**, M. Bloch, and C. Rozell. Feedback coding for active learning. In *The 24th International Conference on Artificial Intelligence and Statistics (**AISTATS**)*, April 2021. (Acceptance rate 30%).

4. M. Connor, **G. Canal**, and C. Rozell. Variational autoencoder with learned latent structure. In *The 24th International Conference on Artificial Intelligence and Statistics (**AISTATS**)*, April 2021. (Acceptance rate 30%).

5. M. O'Shaughnessy, **G. Canal**, M. Connor, M. Davenport, and C. Rozell. Generative causal explanations of black-box classifiers. In *The 34th Conference on Neural Information Processing Systems (**NeurIPS**)*, December 2020. (Acceptance rate 20%).

6. **G. Canal***, S. Fenu*, (equal contribution) and C. Rozell. Active ordinal querying for tuplewise similarity learning. In *AAAI Conference on Artificial Intelligence (**AAAI**)*, New York, NY, February 2020. **Selected for oral presentation**. (Acceptance rate 20%).

7. **G. Canal**, A. Massimino, M. A. Davenport, and C. J. Rozell. Active embedding search via noisy paired comparisons. In *The 36th International Conference on Machine Learning (**ICML**)*, Long Beach, CA, June 2019. **Selected for long oral presentation**. (Acceptance rate 23%).

Journal Articles

1. **G. Canal**, Y. Diaz-Mercado, M. Egerstedt, and C. Rozell. A low-complexity brain-computer interface for high-complexity robot swarm control. In *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 2023.

Refereed Conference Publications

1. J. Zhang, Y. Chen, **G. Canal**, S. Mussmann, Y. Zhu, S. Du, K. Jamieson, and R. Nowak. LabelBench: a comprehensive framework for benchmarking label-efficient learning. In *The 40th International Conference on Machine Learning DMLR Workshop*, Honolulu, HI, July 2023.

2. **G. Canal**, M. Connor, J. Jin, N. Nadagouda, M. O'Shaughnessy, C. Rozell, and M. Davenport. The Picasso algorithm for Bayesian localization via paired comparisons in a union of subspaces model. In *2020 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, May 2020.

3. **G. Canal***, M. O'Shaughnessy*, (equal contribution) C. Rozell, and M. Davenport. Joint estimation of trajectory and dynamics from paired comparisons. In *International Workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP)*, Guadeloupe, West Indies, December 2019.

4. **G. Canal**, A. Massimino, M. A. Davenport, and C. J. Rozell. Active embedding search via noisy paired comparisons. In *Signal Processing with Adaptive Sparse Structured Representations (SPARS) Workshop*, Toulouse, France, July 2019. Poster presentation.

5. **G. Canal**, S. Manivasagam, S. Liang, and C. J. Rozell. Interactive object segmentation with noisy binary inputs. In *Proceedings of the IEEE Global Conference on Signal and Information Processing (GlobalSIP)*, Anaheim, CA, November 2018. Poster presentation.

Conference Abstracts

1. **G. Canal**, S. Fenu, A. Massimino, M. A. Davenport, and C. J. Rozell. Informative ordinal querying for similarity embedding construction and search. In *Coordinated Science Laboratory Student Conference*, Urbana, IL, February 2019. Poster presentation.

2. **G. Canal**, Y. Diaz-Mercado, M. Egerstedt, and C. J. Rozell. Controlling high-complexity robotic swarms with low-complexity eeg brain-computer interfaces. In *International BCI Meeting*, Pacific Grove, CA, May 2018. **Selected for oral presentation**.

3. **G. Canal**, Y. Diaz-Mercado, M. Egerstedt, and C. Rozell. Controlling high-complexity robotic swarms with low-complexity EEG brain-machine interfaces. In *Society for Neuroscience Annual Meeting*, Washington, D.C., November 2017. Poster presentation.

PATENTS

1. M. O'Shaughnessy, G. Canal, M. Connor, M. Davenport, C.J. Rozell. Methods for generating and providing causal explanations of artificial intelligence models and devices thereof, filed June 24, 2021. Patent application number PCT WO2021/262972.

2. G. Canal, C.J. Rozell, S. Fenu, M. Davenport, A. Massimino. Systems and Methods for Preference and Similarity Learning, filed February 3, 2020. International (PCT) Patent Application No.: PCT/US2020/016379.