

Sugandha Sharma

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Education

PhD Brain and Cognitive Sciences, Massachusetts Institute of Technology 2018-Present
Fiete Lab and Tenenbaum Lab (cocosci)

Advisors: Prof. Ila Fiete and Prof. Josh Tenenbaum

Thesis: Functional advantage of hierarchical spatial representations for exploration of novel spaces, and the underlying mechanisms for spatial encoding in the hippocampal complex.

- Leveraging these mechanisms for learning the structure of the world, represented in a way that can support flexible downstream behavior not just in physical space but also for abstract relational tasks beyond space.
- Building biologically constrained neural models that learn structural priors using grid cell and place cell circuits, enabling generalization of structural knowledge across spatial environments and non-spatial relational domains.
- Built a content addressable memory model that exhibits graceful degradation of information per memory as the number of memories stored in a fixed network are increased beyond its critical capacity.
- Conducted human behavioral experiments and built map induction based computational models of exploration in novel environments that outperform state of the art POMCP based planning models.
- Mentored and worked with three undergraduate researchers on sub-components of above projects.

Keywords: Spatial Navigation, Memory, Biologically Constrained Neural Networks, Structure learning, Cognitive Science, Bayesian Framework, Program Induction, Planning, Exploration.

MASc Systems Design Engineering, University of Waterloo 2016-2018
Computational Neuroscience Research Group

Thesis: Neural plausibility of bayesian inference, **Advisor:** Professor Chris Eliasmith

- Proposed a method for representing probability distributions in neural networks that enhanced performance on inference tasks (relative to an ideal bayesian model) due to the neural tuning curves.
- Proposed algorithms, neural computations and mechanisms for online learning of the priors from life experience.

BASc Electrical Engineering, University of Waterloo 2010-2015
Honors Electrical Engineering, With Distinction, Dean's Honors List.

Design Project: Intelligent Sensation and Eyesight Emulation Unit - an assistive aid for visually impaired.

Award: Baylis Medical Capstone Design Project Award (\$5000 to a group of 4).

Additional Research Experience

Visiting Researcher, Stanford Cognitive and Systems Neuroscience Lab May-August, 2017
Stanford University, California; Advisor: Vinod Menon

- Technical report: Sharma, S., Eliasmith, C., & Menon, V. (2017). A Spiking Neural Model of the Oddball Deviance Detection Task: Sensory Adaptation, Evidence Accumulation, and Relation to the P300 Evoked Response.

- Observed MRI scan sessions (fMRI, rest fMRI, sMRI and DTI).

Research Assistant, Computational Neuroscience Research Group

Jan-Dec, 2015

University of Waterloo, ON; Advisor: Chris Eliasmith

Worked part-time as an undergraduate from Jan-April and full time from May-Dec.

- Developed neural models of large scale systems to replicate behavioral performance on cognitive tasks.
 - Methods: (1) population temporal coding in spiking neurons, (2) computing transformations of neural representations, and (3) characterizing neural dynamics in recurrent populations of neurons using control theory
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Publications

Sharma, S., Chandra, S., & Fiete, I. (2022). Content addressable memory without catastrophic forgetting by heteroassociation with a fixed scaffold. *International Conference on Machine Learning*, 2022.

Sharma, S., Curtis, A., Kryven, M., Tenenbaum, J., & Fiete, I. (2022). Map Induction: Compositional spatial submap learning for efficient exploration in novel environments. *International Conference on Learning Representations*, 2022.

Klukas, M., **Sharma, S.**, & Fiete, I. (2022) Fragmented Spatial Maps from Surprisal: State Abstraction and Efficient Planning. Under Review.

Sharma, S., Chandra, S., Chaudhuri, R., Klukas, M., & Fiete, I. The Entorhinal-Hippocampal Attractor Network: recognition and approximate reconstruction of exponentially many arbitrary patterns for high capacity associative and sequence memory. In Preparation.

Sanders, H., Wilson, M., Klukas, M., **Sharma, S.**, & Fiete, I. (2020). Efficient Inference in Structured Spaces. *Cell*, 183(5), 1147-1148.

Sharma, S., (2018). Neural Plausibility of Bayesian Inference. UWSpace. <http://hdl.handle.net/10012/13503>

Sharma, S., Voelker, A., & Eliasmith, C. (2017). A Spiking Neural Bayesian Model of Life Span Inference. *Proceedings of the 39th annual conference of the Cognitive Science Society*. (3131-3136).

Sharma, S., Komer, B., Stewart, T., & Eliasmith, C. (2016). A Neural Model of Context Dependent Decision Making in the Prefrontal Cortex. *Proceedings of the 38th annual conference of the Cognitive Science Society*. (1122 - 1127).

Sharma, S., Aubin, S., & Eliasmith, C. (2016). Large-scale cognitive model design using the Nengo neural simulator. *Biologically Inspired Cognitive Architectures*. 17(2212-683X): 86-100.

Sharma, S., & Tripp, B. (2016). How is scene recognition in a convolutional network related to that in the human visual system? *Proceedings of the 25th International Conference on Artificial Neural Networks*. (9886): 280 - 287.

Talks

Content addressable memory without catastrophic forgetting by heteroassociation with a fixed scaffold. **NAISys 2022**. From Neuroscience to Artificially Intelligent Systems.

Efficient representations for planning and exploration: fragmenting cognitive spaces into compositional submaps. **Cosyne 2022** workshop: Linking phenomena across levels of analysis: The need for a new multi-level reverse-engineering toolkit.

Map Induction: Compositional Spatial Submap Learning for Efficient Exploration in Novel Environments. **ICML 2022** workshop: Beyond Bayes: Paths Towards Universal Reasoning Systems (contributed talk).

Memory Scaffolds in Hippocampal-Entorhinal circuits. **Simons Collaboration on the Global Brain 2022, Stanford**

Compositional Spatial Maps. **Brains on Brains Symposium 2021**. Department of Brain and Cognitive Sciences, MIT.

Rapid generalization of knowledge in structured domains. **MIT BCS Department seminar 2020**.

Poster Presentations

Sugandha Sharma, Aidan Curtis, Marta Kryven, Josh Tenenbaum, Ila R. Fiete. Map Induction: Compositional spatial submap learning for efficient exploration in novel environments. ICLR 2022.

Sugandha Sharma, Sarthak Chandra, Ila R. Fiete. Content addressable memory without catastrophic forgetting by heteroassociation with a fixed scaffold. ICML 2022.

Sugandha Sharma, Sarthak Chandra, Ila R. Fiete. A stable memory scaffold with heteroassociative learning produces a content-addressable memory continuum. Cosyne 2022.

Sugandha Sharma, Aidan Curtis, Marta Kryven, Josh Tenenbaum, Ila R. Fiete. Map Induction: Compositional spatial submap learning for efficient exploration in novel environments. Cosyne 2022.

Sharma, Sugandha, Chandra, Sarthak, Chaudhuri, Rishidev, Klukas, Mirko; Fiete, Ila. Modular Networks with random projections for high-capacity associative pattern and sequence memory. ICLR 2021 Workshop: Generalization beyond the training distribution in brains and machines.

Sugandha Sharma, Sarthak Chandra, Rishidev Chaudhuri, Mirko Klukas, Ila R. Fiete. Randomly mixed modular grid-place cell network for high capacity associative memory. Cosyne 2021.

Sugandha Sharma, Sarthak Chandra, Ila R. Fiete. Recognition and approximate reconstruction of exponentially many arbitrary patterns leading to a Content-Addressable Memory Continuum. SFN 2021.

Mirko Klukas, **Sugandha Sharma**, Ila R. Fiete. Fragmented spatial maps from surprisal and affordances. Cosyne 2021.

Mirko Klukas, **Sugandha Sharma**, Ila R. Fiete. Representing non-Euclidean spaces and abstract data structures with grid cells and place cells. NAISys 2020.

Sugandha Sharma, Aaron Voelker, Chris Eliasmith. A Spiking Neural Bayesian Model of Life Span Inference. Cogsci 2017.

Sugandha Sharma, Brent Komer, Terry Stewart, Chris Eliasmith. A Neural Model of Context Dependent Decision Making in the Prefrontal Cortex. Cogsci 2016.

Sugandha Sharma, Bryan Tripp. How is scene recognition in a convolutional network related to that in the human visual system? ICANN 2016.

Awards and Honors

K. Lisa Yang Integrative Computational Neuroscience (ICoN) Fellowship	\$100,000	2021-2022
Brain and Cognitive Sciences Graduate Student Fellowship, MIT	\$45,000	2020-2021
Brain and Cognitive Sciences Graduate Student Fellowship, MIT	\$45,000	2019-2020

Henry E. Singleton Graduate Student Fellowship, MIT BCS	\$45,000	2018-2019
Holubow Graduate Student Fellowship, MIT BCS	\$45,000	2018-2019
NSERC Canada Graduate Scholarship - Doctoral (3 yrs, declined)	\$35,000/yr	2019 - 2022
NSERC Canada Graduate Scholarship - Masters	\$17,500	2017 - 2018
President's Graduate Scholarship, University of Waterloo	\$5,000	2017 - 2018
President's Grad. Scholarship (Match Eng), University of Waterloo	\$5,000	2017 - 2018
QEII-Graduate Scholarship in Science and Technology	\$15,000	2016 - 2017
President's Graduate Scholarship, University of Waterloo	\$5,000	2016 - 2017
European Neural Networks Society Student Award	\$400	Spring 2016
University of Waterloo Graduate Scholarship	\$1667	Fall 2016
Undergraduate Student Research Award, NSERC	\$4,500	2014 - 2015
Undergraduate Research Assistantship, University of Waterloo	\$800	Winter 2015
Gerry Heckman Scholarship	\$3,000	2014 - 2015
Baylis Medical Capstone Design Project Award (grp. Of 4)	\$5,000	2014 - 2015
Ontario Power Generation Engineering Award	\$2,400	2011 - 2012
Ontario Professional Engineers Foundation Scholarship	\$1,250	2011 - 2012
Awarded UW merit scholarship, University of Waterloo	\$1,000	2010 - 2011

4 x Dean's Honors List for academic distinction, University of Waterloo
 Fall 2010, Spring 2012, Winter 2013, Winter 2015

Teaching Experience

Teaching Assistant, Brain and Cognitive Sciences, MIT

Feb-May 2020

- Course: Machine Motivated Human Vision. Supervised multiple projects on computer vision and human vision.
- Gave lectures on Artificial neural networks (deep nets), Convolutional Neural Networks and Amazon Mechanical Turk for conducting human behavioral experiments.

Teaching Assistant, Brain and Cognitive Sciences, MIT

Sept-Dec 2019

- Set-up infrastructure for a newly introduced graduate level course on Neural Circuits for Cognition.
- Developed assignments and their solutions (including theory, analytics and simulations); held weekly office hours.

Teaching Assistant, University of Waterloo

Sept 2015-Dec 2015

- Taught tutorials to a class of 96 second year Eng. students. Course: Engineering Economics of Design.
- Held weekly office hours, marked assignments, quizzes and exams.

Instructor, Nengo Summer School on large-scale brain modeling

June 2015 and June 2016

Computational Neuroscience Research Group, University of Waterloo

- Working Memory (2015): Attended as a participant and worked in a group of four to build a neural model of working memory. We successfully reproduced the recency and primacy effect plots as found in the human data.
- Sequence Conditioning (2016): Facilitated as an instructor and helped in building a neural model of sequence conditioning. Also served as a social convenor: organized opening BBQ, banquet and weekend social activities.

Instructor, Transforming Education

Sept 2014-Dec 2014

- Taught a coursera course on Programming in Python to a group of 16 CS and Eng. students in India. Taught via Skype. One of the final projects was selected in the top 10 projects in the online class of thousands of students.

Tutor, Tutoring Beyond Borders

Waterloo, ON, June 2011-June 2013

- Volunteered to provide tutoring sessions to three grade 12/10 students in Mathematics, Science and English.

Industry Experience

Software Developer, Advanced Micro Devices (AMD)

Markham, ON, Sept-Dec 2014

Kernel Mode Driver Development to enable graphics chips to work with the latest Windows operating system (C++).

Systems Engineer, Nvidia

Santa Clara, CA, Jan-May 2014

Used Control Systems theory and stability analysis to design compensation circuits for power converters used on graphics cards. Automated existing efficiency measurement procedures (Python) which saved hours of time.

Systems Engineer, Nvidia

Santa Clara, CA, April-Aug 2013

Developed a web user interface (Perl/Html) for an Asset Tracker database.

Wrote QA procedures (Perl) for a hard drive cloning system.

Took initiative to automate internal processes in PCB assembly and fabrication facilities (VBA).

Software Developer, Blackberry

Waterloo, ON, Sept-Dec 2012

Developed Exception Sender and Bug Extractor tools for the Duplicate Defect Detection research project (Java). Gained experience in Information retrieval techniques, search engines and wireless communication systems.

Software Engineer, Phoenix Interactive Design Inc.

London, ON, Jan-April 2012

Developed ATM applications: Asset Manager to track assets on ATM terminals, and an On-Screen Keyboard - a virtual touch screen keyboard displayed on the ATM machine used as an alternative to the physical pin-pad.

Engineering Software Tools Administrator, Christie Digital Systems

Kitchener, ON, May-Aug 2011

Successfully redesigned the User Interface of the Product Lifecycle Management System to provide better search criteria. Delivered a Technical Presentation to train the developers in the new UI (user interface) functionality.

Extra Curricular Activities

Founder, Computational and Theoretical Neuroscience journal club

Nov 2018 - Dec 2021

- Founder and Lead organizer of a journal club across MIT and Harvard
- Brought together a community of grad students, postdocs and professors
- Expanded the existing community across seven academic and industrial institutions
- Conducted biweekly meetings to discuss state of the art research and facilitated collaborations across institutions

Others

Diversity Representative, Fiete Lab, MIT BCS	March 2021 - present
Treasurer, Tang Hall MIT Graduate Residence	May 2021 - April 2022
Social Chair, Tang Hall MIT Graduate Residence	May 2020 - April 2021
Sports Chair, Tang Hall MIT Graduate Residence	May 2019 - April 2020
Instructor, MIT Educational Studies Program	July 2019, July 2021
Volunteer, MIT Museum Girls Day	March 2019
Mentor, Boarding Pass for Success	June 2019
Canada Day Executive, UW Community Relations and Events team	July 2016
Counselor, Women's Center, University of Waterloo	May - Aug 2016
Positive role model, Canadian Mental Health Association	Oct 2015 - April 2016
Dance Performer, UW Indian Cultural Association	2015-2017
Mentor, Women in Engineering, University of Waterloo	Sept 2010 - 2013
Engineering Orientation leader, University of Waterloo	2011
Director Year Spirit, Engineering Society, University of Waterloo	2011
Student Representative, UW Housing and Residences Advisory Board	Sept-Dec 2010