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: Hierarchical spatial representations for exploration and planning in complex 3D environments, and the underlying mechanisms for spatial coding in the brain's hippocampal complex.

- Learning **world models** (the structure of the world), represented in a way that can support flexible downstream behavior not only in physical space, but also for abstract relational tasks beyond space.
- Built biologically constrained **neural network 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 (MESH) using a **deep neural network with one-shot unsupervised learning** to enable efficient use of memory resources. MESH exhibits graceful degradation of information per memory as the number of memories stored in a fixed network are increased beyond capacity.
- Built Map Induction based **generative inference models** (using model-based **reinforcement learning & program induction**) for efficient exploration of novel environments, that outperform state of the art monte carlo planners in partially observed environments.
- Supervised three undergraduate researchers on sub-components of above projects.

Interests: Spatial Navigation, Exploration, Planning, Memory, Theoretical/Computational Neuroscience, Deep Neural Networks, Structure Learning, Reinforcement Learning, Program Induction, Generative Inference, Generative AI, LLMs.

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.
- Implemented algorithms, neural computations and mechanisms for online learning of 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).

Industrial Research Experience

Research Scientist, Microsoft Research
NYC/Redmond, May-Aug, 2023

- Developing ML methods (unsupervised learning) to analyze and predict behavior in a large-scale human gameplay dataset in a multiplayer game called Bleeding Edge.
- Building LLM based artificial agents using player-style identification from human-gameplay analysis that allows training of AI agents for targeted behavior replication. The agents are trained using imitation learning methods.

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.

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.

Publications

Sharma, S., Davidson, G., Kanervisto, A., Khetarpal, K., Arora, U., Hofmann, K., Momennejad, I. (2023). Human-agent alignment in large-scale multi-player games. In Preparation.

Sharma, S., Chandra, S., & Fiete, I. (2023). Model of hippocampal episodic memory unified with and enabled by prestructured spatial representations. In Preparation.

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. *bioArxiv*.

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., & 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.

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.

Talks

Topological data analysis and persistent homology for unsupervised decoding through manifold identification of high dimensional data. **Microsoft Research 2023.**

Map Induction: Compositional spatial submap learning for efficient exploration in novel environments. **Microsoft Research 2023.**

Functional utility of hierarchical spatial representations and their underlying mechanisms in the Hippocampal Complex. **MIT BCS Departmental Seminar 2023.**

Content addressable memory without catastrophic forgetting by heteroassociation with a fixed scaffold. **NAISys 2022**.

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).

Content addressable memory without catastrophic forgetting by heteroassociation with a fixed scaffold. **ICML 2022**. (spotlight talk)

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

Functional advantage of hierarchical spatial representations in humans, and the underlying mechanisms in the Hippocampal Complex, **Poggio Lab, MIT 2022**

Content addressable memory without catastrophic forgetting by heteroassociation with a fixed scaffold. **Robert Yang Lab, MIT 2022**.

Compositional Spatial Maps. **Brains on Brains Symposium**, **MIT 2021**.

Rapid generalization of knowledge in structured domains. **MIT BCS Departmental Seminar 2020**.

Poster Presentations

Sugandha Sharma, Sarthak Chandra, Ila R. Fiete. A mechanistic model for the formation of globally consistent maps of space in complex environments. Cosine 2023.

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

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, ICML 2022, Cosyne 2022, Cogsci 2022.

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

Industrial Engineering 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.

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 Deep neural networks, 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

- Gave tutorial lectures to a class of 96 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.

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

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
