# Aaron Russell Voelker

Ph.D – Senior Research Scientist
Applied Brain Research Inc.
Waterloo, ON, Canada
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## Education

2013/09 – 2019/05 **Ph.D Computer Science**, Centre for Theoretical Neuroscience, University of Waterloo, ON (96% GPA) Thesis: Dynamical Systems in Spiking Neuromorphic Hardware – Defended: April 25, 2019

2008/09 – 2013/04 **BMath Double Honours, Computer Science and Combinatorics & Optimization (Co-op Program)**, University of Waterloo, ON
Dean's Honours List with Distinction

2004/09 – 2008/06 **Ontario Secondary School Diploma (Gifted Program)**, Bell High School, Nepean, ON
Award of Excellence

## Teaching Experience

2018/01 – 2018/04 **Sessional Instructor**, CS 116
26 lectures, office hours, assignment and exam creation – student evaluation: 4.69/5.0 for treatment of student questions and 4.4/5.0 overall

2017/01 – 2017/04 **Sessional Instructor**, CS 116
26 lectures, office hours, assignment and exam creation – student evaluation: 4.72/5.0 for explanations and 4.3/5.0 overall

2015/09 – 2015/12 **Instructional Assistant**, CS 245E
Two lectures, tutorials, office hours, proofreading course content

2015/01 – 2015/04 **Instructional Assistant**, CS 116X
Labs, proofreading course content

2014/09 – 2014/12 **Instructional Assistant**, CS 115X
Labs, proofreading course content

2014/05 – 2014/08 **Instructional Assistant**, CS 115
Labs

2013/09 – 2014/04 **Teaching Assistant**, CS 115
Marking

## Research Experience

2013/09 – 2019/05 **Computational Neuroscience Research Group**, Centre for Theoretical Neuroscience
University of Waterloo, Waterloo, ON

Research under the supervision of Chris Eliasmith: development work on in-house simulation software, Nengo & NengoLib; and theoretical work, in collaboration with Stanford and Yale, programming dynamical systems on the spiking neuromorphic chip, Braindrop.

## Work Experience

2019/03 – *Present* **Senior Research Scientist, Applied Brain Research Inc.**, Waterloo, ON
Developing the next generation of neuromorphic hardware, algorithms, and software.

2012/05 – 2012/12 **Software Engineer (Co-op), Google**, Kitchener, ON
Developed software to analyze advertisement data using machine learning techniques.

2011/09 – 2011/12 **Software Engineer (Co-op), Wish**, San Francisco, CA
Developed software to match products with users using machine learning techniques.

2011/01 – 2011/04 **Software Engineer (Co-op), ContextLogic Inc.**, San Francisco, CA
Developed software to serve advertisements using natural language processing.

2010/05 – 2010/08 **Software Engineer (Co-op), Amazon.com**, Seattle, WA
Developed software to analyze big data using MapReduce.

## Professional Experience

2015/09 – 2019/05 **Teaching**, CS 116, 245E
Sessional instructor, twice, for CS 116 (26 x 80 minute lectures). Guest lectures for the enriched version of CS 245E (2 x 80 minute lectures).

2013/09 – 2019/05 **Talking**, Centre for Theoretical Neuroscience
Given 15 publicly scheduled talks at the CTN on my research: superparamagnetic clustering, heteroassociative memory, temporal representation (part I), temporal representation (part II), gradient descent in neural networks, neural sum-product networks, delaying signals with recurrent networks, choosing encoders, touch classification seminar, locality sensitive hashing, dynamical systems in spiking neural networks, geometric decoder optimization, delay time cells, NengoLib, and biologically plausible LSTMs.

2014/09 – 2015/04 **Mentoring**, Centre for Theoretical Neuroscience
Helped co-supervise an undergraduate student, Amir-Hossein Karimi, from the University of Toronto. Provided guidance throughout his undergraduate thesis on benchmarking adaptive control algorithms through brainstorming, answering questions, and providing feedback.

2014/05 – 2014/05 **Volunteering**, Centre for Education in Mathematics and Computing
Lived with high-school students for one week, while they competed in the Canadian Computing Olympiad. Responsible for moving them between scheduled sessions, answering their questions, and inspiring them to study at the University of Waterloo.

## Publications and Presentations

### Journal Publications

Neckar, A., Fok, S., Benjamin, B. V., Stewart, T. C., Oza, N. N., **Voelker, A. R.**, Eliasmith, C., Manohar, R., and Boahen, K. (2019, January) Braindrop: A mixed-signal neuromorphic architecture with a dynamical systems-based programming model. *Proceedings of the IEEE, 107*:144–164, 2019.

**Voelker, A. R.**, and Eliasmith, C. (2018, March) Improving spiking dynamical networks: Accurate delays, higher-order synapses, and time cells. *Neural Computation, 30*(3): 569–609.

Rasmussen, D., **Voelker, A. R.**, and Eliasmith, C. (2017, July 6) A neural model of hierarchical reinforcement learning. *PLoS ONE, 12*(7): 1–39.

Aubin, S., **Voelker, A. R.**, and Eliasmith, C. (2016, December 26) Improving with practice: A neural model of mathematical development. *Topics in Cognitive Science, 9*(1): 6–20.

**Voelker, A. R.**, Friedl, K. E., Peer, A., and Eliasmith, C. (2016, January 12) Human-inspired neurorobotic system for classifying surface textures by touch. *IEEE Robotics and Automation Letters, 1*(1): 516–523.

Bekolay, B., Bergstra, J., Hunsberger, E., DeWolf, T., Stewart, T. C., Rasmussen, D., Choo, X., **Voelker, A. R.**, and Eliasmith, C. (2014, January 6) Nengo: A Python tool for building large-scale functional brain models. *Frontiers in Neuroinformatics, 7*(48): 1–13.

## Conference Publications

**Voelker, A. R.**, Kajić, I., and Eliasmith, C. (2019, December) Legendre Memory Units: Continuous-Time Representation in Recurrent Neural Networks. *In Advances in Neural Information Processing Systems (NeurIPS), 15544–15553* (International conference), 10 page paper & poster. **(*) Spotlight Presentation**

De Jong, J., **Voelker, A. R.**, Van Rijn, H., Stewart, T. C., and Eliasmith, C. (2019, October) A neurocomputational account of ecologically plausible, flexible timing with Legendre memory. *In 2nd Annual Conference of the Timing Research Forum* (International conference), abstract & poster.

De Jong, J., **Voelker, A. R.**, Van Rijn, H., Stewart, T. C., and Eliasmith, C. (2019, July) Flexible timing with delay networks – The scalar property and neural scaling. *In 17th Annual Meeting of the International Conference on Cognitive Modelling (ICCM)* (International conference), 6 page paper.

Komer, B., Stewart, T. C., **Voelker, A. R.**, and Eliasmith, C. (2019, July) A neural representation of continuous space using fractional binding. *Proceedings of the 41st Annual Conference of the Cognitive Science Society* (International conference), 6 page paper & poster.

Lu, T., **Voelker, A. R.**, Komer, B., and Eliasmith, C. (2019, July) Representing spatial relations with fractional binding. *Proceedings of the 41st Annual Conference of the Cognitive Science Society* (International conference), 6 page paper & poster.

Stöckel, A., **Voelker, A. R.**, and Eliasmith, C. (2018, March) Nonlinear synaptic interaction as a computational resource in the Neural Engineering Framework. *Computational and Systems Neuroscience (Cosyne)* (International conference), 2 page abstract & poster.

Gosmann, J., **Voelker, A. R.**, and Eliasmith, C. (2017, July) A spiking independent accumulator model for winner-take-all computation. *Proceedings of the 39th Annual Conference of the Cognitive Science Society* (International conference), 6 page paper & poster.

Sharma, S., **Voelker, A. R.**, and Eliasmith, C. (2017, July) A spiking neural Bayesian model of life span inference. *Proceedings of the 39th Annual Conference of the Cognitive Science Society* (International conference), 6 page paper & poster.

K.-Abrams, E., Gilbert, A., **Voelker, A. R.**, Benjamin, B. V., Stewart, T. C., and Boahen, K. (2017, May 31) A population-level approach to temperature robustness in neuromorphic systems. *In IEEE International Symposium on Circuits and Systems (ISCAS)* (International conference), 4 page paper & oral presentation.

**Voelker, A. R.**, Benjamin, B. V., Stewart, T. C., Boahen, K., and Eliasmith, C. (2017, May 30) Extending the Neural Engineering Framework for nonideal silicon synapses. *In IEEE International Symposium on Circuits and Systems (ISCAS)* (International conference), 4 page paper & poster.

Aubin, S., **Voelker, A. R.**, and Eliasmith, C. (2016, August) Improving with practice: A neural model of mathematical development. *Proceedings of the 38th Annual Conference of the Cognitive Science Society* (International conference), 6 page paper & oral presentation. **(*) Best Student Paper Award**: Computational Modeling Prize in Applied Cognition

Knight, J., **Voelker, A. R.**, Mundy, A., Eliasmith, C., and Furber, S. (2016, July) Efficient SpiNNaker simulation of a heteroassociative memory using the Neural Engineering Framework. *The 2016 International Joint Conference on Neural Networks (IJCNN)* (International conference), 8 page paper & oral presentation.

**Voelker, A. R.**, Crawford. E., and Eliasmith, C. (2014, July 17) Learning large-scale heteroassociative memories in spiking neurons. *Unconventional Computation and Natural Computation* (International conference), abstract & poster presentation.

## Invited Talks

**Voelker, A. R.** (2019, October 18) Legendre Memory Units: Continuous-Time Representation in Recurrent Neural Networks. *Intel's Neuromorphic Research Community* (International workshop), presentation.

**Voelker, A. R.** (2019, October 15) Theories of Computation and Large-scale Brain Models. *Semiconductor Research Corporation – Workshop on the New Compute Trajectories for Energy-Efficient Computing* (International workshop), panel session.

**Voelker, A. R.** (2019, June 14) Advanced Dynamics and Loihi. *6th Annual Nengo Summer School* (International workshop), tutorial.

**Voelker, A. R.** (2018, October 2) Implementing delay networks on SNN hardware. *Intel's Neuromorphic Research Community* (International workshop), presentation.

**Voelker, A. R.** (2018, June 12) Advanced dynamics in Nengo. *5th Annual Nengo Summer School* (International workshop), tutorial.

**Voelker, A. R.** (2017, October 5) Precise dynamics with idiosyncratic silicon synapses. *Stanford, Neuromorphics: Programmable analog computation through probabilistic digital communication* (Annual program review), presentation.

**Voelker, A. R.**, and Stewart, T. C. (2017, June 29) Dynamics and control in spiking neurons. *Telluride Neuromorphic Cognition Engineering Workshop* (International workshop), tutorial.

**Voelker, A. R.** (2017, June 9) Representing time in spiking dynamical networks. *4th Annual Nengo Summer School* (International workshop), tutorial.

**Voelker, A. R.** (2016, June 10) Reservoir Computing with Nengo. *3rd Annual Nengo Summer School* (International workshop), tutorial.

**Voelker, A. R.** and Eliasmith, C. (2015, December 8) Computing with temporal representations using recurrently connected populations of spiking neurons. *Connecting Network Architecture and Network Computation* (International workshop), abstract & oral presentation.

**Voelker, A. R.** (2015, June 16) Dynamics, delays, and temporal representation. *2nd Annual Nengo Summer School* (International workshop), tutorial.

**Voelker, A. R.** (2015, April 22) Implementing some useful building blocks in Nengo. *University of Manchester* (Invited talk), presentation.

Crawford, E., and **Voelker, A. R.** (2014, June 17) Knowledge representation [in Nengo]. *1st Annual Nengo Summer School* (International workshop), tutorial.

Bekolay, T., and **Voelker, A. R.** (2014, June 13) Learning [in Nengo]. *1st Annual Nengo Summer School* (International workshop), tutorial.

## Patents

Multi-bit Spike Computation, Communication, and Scaling. **Voelker, A. R.** and Eliasmith, C. Applied Brain Research Inc. US Patent App. 62/929,722, 2019 (Provisional).

Neuromorphic Associative Memories for Database Queries. **Voelker, A. R.**, Eliasmith, C., and Blouw, P. Applied Brain Research Inc. US Patent App. 62/929,713, 2019 (Provisional).

A neural representation of continuous space using fractional binding. Komer, B., Stewart, T. C., **Voelker, A. R.**, and Eliasmith, C. Applied Brain Research Inc. US Patent App. 62/820,089, 2019 (Provisional).

Dynamical systems in spiking neuromorphic hardware. **Voelker, A. R.** and Eliasmith, C. Applied Brain Research Inc. US Patent App. 62/814,767, 2019 (Provisional).

Methods and systems for implementing dynamic neural networks. **Voelker, A. R.** and Eliasmith, C. Applied Brain Research Inc. US Patent App. 15/243,223, 2018 (Pending).

Determining whether to send a call-out to a bidder in an online content auction. Young-Lai, M., Milley, P. L., Bokharaei, S. H-K., Suszko, J. Z-P., and **Voelker, A. R.** Google Inc. PCT/US2014/010432, WO2015005950A1, US20170193564A1, 2014 (Accepted).

## Other Publications

**Voelker, A. R.** (2019, March 10) Dynamical Systems in Spiking Neuromorphic Hardware. *University of Waterloo*, PhD Thesis, 235 pages.

Stöckel, A., **Voelker, A. R.**, and Eliasmith, C. (2017, October 20) Point neurons with conductance-based synapses in the Neural Engineering Framework. *arXiv q-bio.NC* 1710.07659, 24 pages.

**Voelker, A. R.**, and Eliasmith, C. (2017, October 1) Analysis of oscillatory weight changes from online learning with filtered spiking feedback. *Centre for Theoretical Neuroscience*, Technical report, 8 pages.

**Voelker, A. R.**, and Eliasmith, C. (2017, August 27) Methods for applying the Neural Engineering Framework to neuromorphic hardware. *arXiv q-bio.NC* 1708.08133, 11 pages.

**Voelker, A. R.**, Gosmann, J., and Stewart, T. C. (2017, January 4) Efficiently sampling vectors and coordinates from the n-sphere and n-ball. *Centre for Theoretical Neuroscience*, Technical report, 3 pages.

**Voelker, A. R.** (2016, April 18) Advances in locality-sensitive hashing. *CS 860* (Coursework), 11 page paper.

**Voelker, A. R.** (2015, October 1) A solution to the dynamics of the prescribed error sensitivity learning rule. *Centre for Theoretical Neuroscience*, Technical report, 7 pages.

**Voelker, A. R.** (2015, August 27) A biologically plausible Sum-Product Network for language modeling. *CS 886* (Coursework), 18 page paper.

**Voelker, A. R.** (2015, April 1) Implementing hill climbing with a spiking neural network. *CS 898* (Coursework), 4 page paper.

**Voelker, A. R.**, and Eliasmith, C. (2014, April 24) Controlling the Semantic Pointer Architecture with deterministic automata and adaptive symbolic associations. *SYDE 750* (Coursework), 22 page paper.

**Voelker, A. R.** (2013, December 14) Properties of Superparamagnetic Clustering. *CS 886* (Coursework), 12 page paper.

## Honours and Awards

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| 2018/05 – 2019/04 | **Peggy and Tom Mulligan Graduate Scholarship (OGS)** |
| 2018/05 – 2019/04 | **President's Graduate Scholarship** |
| 2016/05 – 2018/04 | **NSERC Alexander Graham Bell Canada Graduate Scholarship – Doctoral (CGS-D)** |
| 2016/05 – 2018/04 | **President's Graduate Scholarship** |
| 2016/01 – 2017/12 | **David R. Cheriton Graduate Scholarship** |
| 2014/09 – 2015/08 | **NSERC Graduate Scholarship – Master's (CGS-M)** |
| 2014/09 – 2015/08 | **GO-Bell Scholarship** |
| 2013/09 – 2015/08 | **David R. Cheriton Graduate Scholarship** |
| 2013/09 – 2015/08 | **President's Graduate Scholarship** |
| 2013/09 – 2014/08 | **Joseph Wai-Hung Liu Graduate Scholarship (OGS)** |
| 2012/01 – 2012/01 | **President's International Experience Award** |
| 2008/09 – 2008/09 | **President's Scholarship of Distinction** |
| 2008/09 – 2008/09 | **René Descartes Scholarship** |
| 2008/08 – 2008/08 | **International Olympiad in Informatics (IOI) – Bronze Medal** |
| 2008/05 – 2008/05 | **Canadian Computing Olympiad – National Champion (*) 1st Place Overall** |