Chankyu Lee

◇ **Phone**: (+1) 765-337-4551 ◇ **Email**: lee2216@purdue.edu ◇ **Website**: https://chan8972.github.io

WORK SUMMARY

Broadly speaking, my research interests lie at the intersection of deep learning and edge computing. I focus on developing energy-efficient and robust deep learning algorithms with special interests in Spiking Neural Networks (SNNs) and computer vision for event-based cameras. Specifically, I designed unsupervised/supervised/semi-supervised/self-supervised learning algorithms for deep SNNs. In addition, I developed motion estimation algorithms for event-based camera in challenging scenes such as high speed and wide dynamic range.

RESEARCH FOCUSES

◇ Machine/Deep Learning ◇ Computer Vision ◇ Algorithm-Hardware Co-design

EDUCATION

Purdue University, West Lafayette, IN, USA *Fall 2015 - Spring 2021*
Ph.D., Electrical and Computer Engineering (Advisor: Prof. Kaushik Roy)

Sungkyunkwan University (SKKU), South Korea *Spring 2009 - Spring 2015*
B.S., Electrical and Electronics Engineering

Hong Kong University of Science and Technology (HKUST), Hong Kong *Fall 2013*
Exchange Student Program, Electronic and Computer Engineering

EXPERIENCE

Center for Brain Inspired Computing (C-BRIC), Purdue University *Aug. 2016 - Dec. 2020*
Graduate Research Assistant *West Lafayette, IN, USA*

- Exploratory research on neuromorphic computing for energy-efficient and robust machine learning, overcoming limitations of current artificial intelligence through algorithm-hardware co-design.
  - Proposed novel unsupervised/supervised/semi-supervised learning algorithms for deep convolutional Spiking Neural Networks (SNNs) to efficiently harness machine learning algorithms in the resource constrained real-world environments. Results are presented in publications [IEEE TCDS, *Frontiers'18*, *Frontiers'20*, *arXiv'20*].
  - Developed motion estimation algorithms for event-based camera in challenging scenes such as high speed and wide dynamic range. Specifically, I presented sparse optical flow estimation using the streams of asynchronous events as well as dense optical flow estimation using sensor fusion method (frame-based images and event streams). Results are presented in publications [*ECCV'20*, *ECCV demo*, *arXiv'21*].

Access Research Laboratory, Bell Labs, Nokia *Summer 2018*
Graduate Internship (Supervisor: Hungkei Chow and Joseph Galaro) *Murray Hill, NJ, USA*

- Developed methodologies of mapping and scheduling convolutional neural network on a specialized MIMD (Multi-Instruction Multi-Data) processor for energy-efficient AI computing.

Graduate School of Convergence Science and Technology, Seoul National University
Summer 2014, Undergraduate Internship (Advisor: Prof. Yoonkyu Song) *Suwon, South Korea*

- Research on mid-field wireless powering for simulating neural signals in the brain-machine interface.
  - Designed a full-wave synchronous four-transistor cell rectifier, fed in parallel into each stage through a pump capacitor in implantable bio-chip antenna transmissions.

ACADEMIC PUBLICATION

- **International Conference**

1. Nitin Rathi, Amogh Agrawal, **Chankyu Lee**, Adarsh Kumar Kosta, Kaushik Roy, "Exploring Spike-Based Learning for Neuromorphic Computing: Prospects and Perspectives", *Design, Automation and Test in Europe Conference (DATE) 2021, Invited Paper.*
2. **Chankyu Lee**, Adarsh Kumar Kosta, Alex Zihao Zhu, Kenneth Chaney, Kostas Daniilidis and Kaushik Roy, "Spike-FlowNet: Event-based Optical Flow Estimation with Energy-Efficient Hybrid Neural Networks", *In Proceedings of the European Conference on Computer Vision (ECCV) 2020, Glasgow, UK.*
3. Gopalakrishnan Srinivasan, **Chankyu Lee**, Abhronil Sengupta, Priyadarshini Panda, Syed Shakib Sarwar and Kaushik Roy, "Training Deep Spiking Neural Networks for Energy-Efficient Neuromorphic Computing", *International Conference on Acoustics, Speech, and Signal Processing (ICASSP) 2020, Barcelona, Spain, Invited Paper.*
4. Saima Sharmin*, Priyadarshini Panda*, Syed Shakib Sarwar, **Chankyu Lee**, Wachirawit Ponghiran and Kaushik Roy, "A Comprehensive Analysis on Adversarial Robustness of Spiking Neural Networks", *International Joint Conference on Neural Networks (IJCNN) 2019, Budapest, Hungary.*

- **International Journal**

1. **Chankyu Lee***, Syed Shakib Sarwar*, Priyadarshini Panda, Gopalakrishnan Srinivasan and Kaushik Roy, "Enabling Spike-based Backpropagation for Training Deep Neural Network Architectures" (*Equally Contributing Authors), *Frontiers in Neuroscience, Neuromorphic Engineering, 2020.*
2. **Chankyu Lee**, Priyadarshini Panda, Gopalakrishnan Srinivasan and Kaushik Roy, "Training Deep Convolutional Spiking Neural Networks with STDP-based Unsupervised Pre-training followed by Supervised Fine-tuning", *Frontiers in Neuroscience, Neuromorphic Engineering, 2018.*
3. **Chankyu Lee**, Gopalakrishnan Srinivasan, Priyadarshini Panda and Kaushik Roy, "Deep Spiking Convolutional Neural Network Trained with Unsupervised Spike Timing Dependent Plasticity", *IEEE Transactions on Cognitive and Developmental Systems (TCDS), 2018, Chosen as popular article for May 2018.*
4. Amogh Agrawal*, Akhilesh Jaiswal*, **Chankyu Lee** and Kaushik Roy, "X-SRAM: Enabling In-Memory Boolean Computations in CMOS Static Random Access Memories", *IEEE Transactions on Circuits and Systems I, 2018.*

- **Preprint & Under Review**

1. **Chankyu Lee**, Adarsh Kumar Kosta and Kaushik Roy, "Fusion-FlowNet: Energy-Efficient Optical Flow Estimation using Sensor Fusion and Deep Fused Spiking-Analog Network Architectures" *arXiv 2021.*
2. Sayeed Shafayet Chowdhury*, **Chankyu Lee*** and Kaushik Roy, "Towards Understanding the Effect of Leak in Spiking Neural Networks" (*Equally Contributing Authors), *arXiv 2020.*
3. Amogh Agrawal, **Chankyu Lee** and Kaushik Roy, "X-CHANGR: Changing Memristive Crossbar Mapping for Mitigating Line-Resistance Induced Accuracy Degradation in Deep Neural Networks", *arXiv 2019.*

PRESENTATION

1. **Chankyu Lee** "Training Deep Spiking Neural Networks for Energy-Efficient Neuromorphic Computing", *Korea Institute of Science and Technology (KIST), Virtual seminar, 2020.*
2. **Chankyu Lee*** and Kenneth Chaney* (*Co-presenter), "Hybrid Approaches on Motion Computation using Event-based Cameras", *Center for Brain-Inspired Computing (C-BRIC), Main presentation at annual review, 2020.*
3. **Chankyu Lee**, Adarsh Kumar Kosta, Alex Zihao Zhu, Kenneth Chaney, Kostas Daniilidis and Kaushik Roy, "Spike-FlowNet: Event-based Optical Flow Estimation with Energy-Efficient Hybrid Neural Networks", *Center for Brain-Inspired Computing (C-BRIC), Industry meeting presentation, 2020.*

4. **Chankyu Lee**, Priyadarshini Panda, Gopalakrishnan Srinivasan and Kaushik Roy, "Learning Useful Representations in Deep Spiking Neural Network using Unsupervised STDP prior to Supervised Fine-tuning", *SRC Techcon 2018, Austin, TX, USA*.

TECHNICAL STRENGTHS

Programming Language	Python, Matlab, C++
Machine Learning Tools	Pytorch, TensorFlow, Numpy, OpenCV

RELEVANT COURSE PROJECTS

• **Algorithm**

– **Artificial Intelligence**: Developed Binary weighted SNNs (BSNNs) to reduce the memory storage and remove batchnorm layers. Stochastic input encoding scheme and a spiking neuron model enable BSNNs to achieve competitive accuracy and perform efficient bit-wise computations without the need of the batchnorm layer. [*Language & Software: Python, Pytorch*]

– **Deep Learning**: Presented dynamic iterative synapse pruning for optimizing toward energy-efficient neural networks. Obtained 38-79% pruning efficiency at 1.5-2.2× increase in training effort across the layers on MNIST and CIFAR-10 datasets. [*Language & Software: Lua, Torch*]

– **Advanced VLSI Design**: Implemented rank-order temporal spike encoding scheme for rapid and energy-efficient classification tasks. Multi-layer convolutional SNNs are trained using unsupervised spike timing dependent plasticity learning. Obtained 3.5×/10× reduction in time-steps/spike-counts during the inference stage compared with a rate-based spike encoding scheme. [*Language: Matlab*]

• **Hardware System**

– **System-on-Chip Design**: Demonstrated in-memory computing within STT-MRAMs memory units for Boolean logic operations. Applied the in-memory computing to AES encryption algorithms and evaluated the 172% energy benefit and 8% performance improvement compared with conventional CPU-based computing. Results are published in *IEEE TCAS-I*. [*Language & Platform: C++, Nios-II processor*]

– **MOS VLSI Design**: Implemented 8-bit wallace tree multiplier with scaled-down supply voltage and boost clock frequency by using the principle of pipelining and detecting critical path to lengthen the clock period in the worst case. [*EDA tool: Cadence Virtuoso, Hspice, Nanosim*]

SERVICE ACTIVITIES

• **Leadership Experience**

– President of Purdue Electrical Engineering Korean Association (PEEKA) in 2017-2018 academic year

– Student ambassador member of 'Qualcomm IT Tour' in summer 2013. Selected as one of top 30 student engineers in Korea and visited Qualcomm's headquarter in San Diego, CA, USA.

• **Technical Reviewer**

– IEEE Transactions on Neural Networks and Learning Systems (TNNLS)
– IEEE Access
– IEEE International Symposium on Circuits and Systems (ISCAS)
– Frontiers in Neuroscience, Neuromorphic Engineering
– Frontiers in Computational Neuroscience
– Journal of Sensors
– International Conference on Computer Science and Application Engineering (CSAE)

REFERENCE

Available Upon Request