

# CURRICULUM VITAE FOR DI WU

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## RESEARCH INTEREST

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Approximate Computing, Unary Computing, Neural Network Optimization

## EDUCATION

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Sep 2017 – Now    **Ph.D Student in Department of ECE** at University of Wisconsin–Madison, USA

- **Advisor:** Joshua San Miguel

Sep 2012 – Jan 2015    **M.E. in IC Engineering** at Fudan University, China

- **Academic Ranking:** 1/67; **GPA Ranking:** 3/67

Sep 2007 – Jun 2012    **B.S. in Micro-Electronics** at Fudan University, China

## HONOR

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May 2020    **Gerald Holdridge Outstanding Teaching Assistant Awards** from UW–Madison

Jun 2019    **Chancellor’s Opportunity Fellowship (COF)** from UW–Madison

Apr 2019    **ASPLOS 2019 SRC Grant** from ACM ASPLOS 2019, Providence, RI

Mar 2019    **Student Research Travel Grant–Conference** from UW–Madison

Mar 2019    **Student Research Competition (SRC) Candidate** in ACM ASPLOS 2019, Providence, RI

Mar 2019    **Final List** in Qualcomm Innovation Fellowship 2019, UW–Madison

Mar 2019    **Winner** in Foxconn SmartCity Competition 2019, UW–Madison

Feb 2019    **Winner of Student Travel Grant** in ACM ASPLOS 2019, Providence, RI

Oct 2018    **The Hiran Mayukh Award** on Computer Architecture Affiliate Meeting 2018, UW–Madison

Sep 2015    **Excellent New Employee Prize** in Hisilicon Technologies Co., Ltd

Mar 2014    **National Scholarship** for Excellent Graduate Student of Fudan University (1/67)

Sep 2007    **Third Prize Scholarship** for Excellent Freshman of Fudan University (3/45)

Jun 2007    **Ranking 88/450,000** in National College Entrance Examination in Anhui Province, China

## PUBLICATION

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### Journal:

**J3.** D. Wu, et al., "In-Stream Correlation-Based Division and Bit-Inserting Square Root in Stochastic Computing", *under review*.

**J2.** D. Wu, Y. Chen, Q. Zhang, Y. Ueng and X. Zeng, "Strategies for Reducing Decoding Cycles in Stochastic LDPC Decoders," in *TCASII*, 2016.

**J1.** Y. Chen, Q. Zhang, D. Wu, C. Zhou and X. Zeng, "An Efficient Multirate LDPC-CC Decoder With a Layered Decoding Algorithm for the IEEE 1901 Standard," in *TCASII*, 2014.

### Conference:

**C10.** D. Wu, et al., "UNO: Virtualizing and Unifying Nonlinear Operations for Emerging Neural Networks," *under review*.

**C9.** D. Wu, R. Yin and J. San Miguel, "Normalized Stability: A Cross-Level Design Metric for Early Termination in Stochastic Computing," in *ASP-DAC*, 2021.

- C8. D. Wu, J. Li, R. Yin, H. Hsiao, Y. Kim and J. San Miguel, "uGEMM: Unary Computing Architecture for GEMM Applications," in *ISCA*, 2020.
- C7. Y. Kim, J. San Miguel, S. Behroozi, T. Chen, K. Lee, Y. Lee, J. Li, and D. Wu, "Approximate Hardware Techniques for Energy-Quality Scaling Across the System," in *ICEIC*, 2020. (Invited)
- C6. D. Wu, T. Chen, C. Chen, O. Ahia, J. San Miguel, M. Lipasti and Y. Kim, "SECO: A Scalable Accuracy Approximate Exponential Function Via Cross-Level Optimization," in *ISLPED*, 2019.
- C5. D. Wu and J. San Miguel, "In-Stream Stochastic Division and Square Root via Correlation," in *DAC*, 2019.
- C4. Q. Zhang, Y. Chen, D. Wu, X. Zeng and Y. Ueng, "Convergence-optimized variable node structure for stochastic LDPC decoder," in *ICASSP*, 2016.
- C3. Q. Zhang, Y. Chen, D. Wu, X. Zeng and Y. Ueng, "An area-efficient architecture for stochastic LDPC decoder," in *DSP*, 2015.
- C2. D. Wu, Y. C., Q. Zhang, L. Zheng, X. Zeng and Y. Ueng, "Latency-optimized stochastic LDPC decoder for high-throughput applications," in *ISCAS*, 2015.
- C1. D. Wu, Y. Chen, Y. Huang, Y. Ueng, L. Zheng and X. Zeng, "A high-throughput LDPC decoder for optical communication," in *ASICON*, 2013.

#### Patent (CN):

- P1. "A high-throughput LDPC decoder for Optical Communication." Y. Chen, D. Wu, Y. Huang
- P2. "A multi-standard high performance FEC decoder." Y. Chen, D. Wu, Y. Huang

## RESEARCH

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Feb 2018 – Now Research Assistant in STACS Lab, Department of ECE, UW–Madison

#### ◇ Approximate Computing

- **RAVEN**: A Reconfigurable Architecture for Varying Emerging Neural Networks. (*Qualcomm Innovation Fellowship 2019 Finalist*)
  - Support both linear and nonlinear functions based on MAC operations.
  - Support both dense and sparse matrix operations with dedicated NoC and sparse data format. (*in progress*)
  - Support different dataflows with dedicated PE array partition and scheduling. (*in progress*)
- **Unified Nonlinear Operation (UNO)**: Design fixed-point UNO architecture to unify both linear and nonlinear operations with MAC operation based on Horner's rule. (*under review*)
  - Support popular nonlinear operations in deep learning and image processing.
  - Support run-time accuracy-energy scaling based on the order of Taylor series.
  - Validate benefits of UNO over counterparts in terms of area, power, and energy efficiency.
  - Apply UNO to emerging DNNs, like CapsNet, GCN and NMT, with negligible accuracy loss.
- **Approximate Exponential Function**: Design a cross-layer optimization framework to achieve the desired accuracy-energy tradeoff for exponentiation based on Taylor series. (*C6, ISLPED 2019*)
  - Support both *static design-time* and *dynamic run-time* accuracy-energy scaling, using an approximate Taylor series to asymptote exponentiation, where division is substituted with shift and multiplication can be skipped.
  - At the algorithm level, optimize the approximate Taylor series of exponentiation with discrete gradient descent for run-time tradeoff.
  - At the circuit level, model the error bound of the approximate Taylor series based on an open source approximate circuit library for design-time tradeoff.

#### ◇ Unary Computing

- **UnarySim**: Construct a PyTorch-based library for unary computing, a computing paradigm based on bit streams. [Github] (*in progress*)
  - Support popular linear and nonlinear operations in unary computing.
  - Support varying unary computing schemes, including stochastic computing and race logic.
  - Provide end-to-end synthesis pipeline from PyTorch to Verilog HDL.
  - Provide demo of popular unary computing applications.
- **System Design Principle for Stochastic Computing**: Design a metric, normalized stability, to characterize early termination for stochastic computing systems to achieve high energy efficiency without losing accuracy acceptance. (*C9, ASP-DAC 2021*)
  - Present the propagation of normalized stability in stochastic computing systems.
  - Identify the competitiveness of computing units for early termination, reducing design space.
  - Predict the timing of early termination for popular applications.
- **Unary General Matrix Multiply (uGEMM)**: Design high-efficiency uGEMM architecture, featured with high parallelism, input insensitivity and early termination. (*C8, ISCA 2020*)
  - Unify the bit stream representation for different unary computing schemes, including both rate-coded stochastic computing and temporal-coded race logic.
  - Unify the linear unary computing operations of varying schemes with strict math proof.
  - Achieve high efficiency and accuracy at both the unit and application level.
- **Bit Stream Generation In DRAM**: Generate random bit streams for stochastic computing with off-the-shelf SDRAM on FPGA.
  - Design processing in memory (PIM) architecture for generating bit streams at maximum DRAM bandwidth.
  - Model the proposed architecture with an in-house simulator designed on our own.
  - Test the randomness of generated bit streams with NIST SP 800-22 statistical test suit.
- **In-stream Stochastic Division and Square Root**: Utilize the correlation among bit streams to perform division and square root with simultaneously lower latency, higher accuracy and cheaper cost. (*C5, DAC 2019, J3, D&T 2020*)
  - Propose proper metrics to mitigate the fluctuation at the output due to feedback loops.
  - Build C++ based simulating platform towards fast and accurate stochastic computing simulation, which is the precedent of UnarySim. [Github]
- **Stochastic CapsNet Architecture**: Optimize the nonlinear stochastic computing units, dataflow-level feedback loops, and logic sharing in Capsule Neural Network. (*ASPLOS 2019 SRC*)

#### ◊ Deep Learning

- **Security Side of Homomorphic Inference**: Perform security analysis on the inference process of plaintext deep learning model and ciphertext data based on homomorphic encryption, and conclude that adversarial attacks can be detected under such threat model.
- **Style Transfer for Medical Images**: Design a neural network with both residual and skip connections, and train it with MS-SSIM for style transfer from Hematoxylin-Eosin (H&E) image to Second Harmonic Generation (SHG) image for collagen fiber extraction. [slides]
- **Automatic Quantization Platform**: Develop Tensorflow library to fast reach the best fixed-point quantization for Deep Neural Networks.

Sep 2017 – Jan 2018 Research Assistant in WiCIL Lab, Department of ECE, UW–Madison

#### ◊ Hardware Architecture for Convolutional Neural Networks

- **Sparse Neural Network**: Prune deep neural network in a hardware-aware manner based on network-on-chip theories to minimize the gap between dense and sparse deep neural network.
  - Analyze the hardware consumption of a channel-level pruned VGG16 model on ImageNet.

- Model the performance for the channel-level pruned VGG16 model.

**Aug 2012 – Jan 2015 State Key Laboratory of ASIC and System, Fudan University**

◇ **High Throughput Low-Density Parity-Check (LDPC) Architecture Design**

- *Stochastic LDPC Architecture*: Design the hardware architecture with better latency for 10GBASE-T with 45nm technology. (*J2, TCASII 2016*)
- *Latency Reduction in Stochastic LDPC decoding*: Optimize latency by introducing a parameter initialization procedure and combining the original stochastic algorithm with a simplified Bit-Flipping algorithm, as well as utilizing precise posterior information. (*C2, ISCAS 2015*)
- *Dual clock edge triggered LDPC decoding*: Design Min-Sum LDPC architecture working on both clock edges for WiMAX. (*C1, AISCON 2013*)

## INDUSTRIAL EXPERIENCE

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**May 2020 – Aug 2020 Research Intern in Cerebras Systems.**

◇ **Numerical Optimization for Deep Neural Network**

- Explore a novel floating-point format for training both CV and language models on wafer-scale engine, CS-1, with FP32 and FP16 as reference.
- Simulate the training process on the real hardware with boundary casting in software simulator.

**May 2019 – Aug 2019 Research Intern in Facebook Inc.**

◇ **Lossless Quantization for Video Model**

- Perform post training quantization for ResNet-50 with Min-Max quantization and distribution-based quantization.
- Perform quantization-aware training for ResNext-50 with channel-wise 3D convolution.

**Mar 2015 – May 2017 Digital Circuit Engineer in Hisilicon Technologies Co., Ltd.**

◇ **Algorithm Analysis for SoC**

- Analyze DSP resource consumption, covering parallelism and ISA.
- Optimize task scheduling for both DSP and SoC.
- Analyze the bandwidth for SoC workload.

◇ **Hardware Design for DSP**

- Design customized ARM AXI-4 bus for DSP cores in SoC.
- Design reconfigurable microarchitecture for multiple functions.
- Perform unit test with formal verification using the Cadence Jaspergold.
- Analyze power consumption for multiple DSP systems.

◇ **Design Automation**

- Automate post-placement-and-route simulation with customized platform.
- Design CAD report analyzing tool for entire hardware design flow.
- Design execution monitoring and analyzing tool for different DSP SDKs.
- Optimize ISA code length using discrete gradient descent.

## SKILL

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**Programming language:** Verilog HDL, Python, C++, Perl, MATLAB

**Hardware:** Modelsim, Design Compiler, VCS, Verdi, Quartus Prime, Vivado

**Software:** PyTorch, TensorFlow, Caffe2

## ACADEMIC ACTIVITY

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**Seq 2020** External Reviewer for HPCA 2021  
**Sep 2020** Teaching Assistant for ECE454 (Mobile Computing Lab), UW–Madison  
**Feb 2020** Guest Lecture on Introduction to Unary Computing on ECE757 (Advanced Computer Architecture II), UW–Madison  
**Jan 2020** Teaching Assistant for ECE554 (Digital Circuit Lab), UW–Madison  
**Jan 2020** External Reviewer for ISCA 2020  
**Jan 2020** External Reviewer for DAC 2020  
**Jan 2020** External Reviewer for ASPLOS AE 2020  
**Seq 2019** Teaching Assistant for ECE554 (Digital Circuit Lab), UW–Madison  
**Apr 2019** External Reviewer for MICRO 2019  
**Apr 2019** ASPLOS 2019 attendee in Providence, RI, USA  
**Mar 2019** Guest Lecture on Deep Neural Network and Stochastic Computing on ECE752 (Advanced Computer Architecture I), UW–Madison  
**Feb 2019** External Reviewer for ISCA 2019  
**Jan 2019** Research Assistant with Prof. Joshua San Miguel  
**Jan 2019** Teaching Assistant for ECE554 (Digital Circuit Lab), UW–Madison  
**Seq 2018** Teaching Assistant for ECE552 (Introduction to Computer Architecture) and ECE554 (Digital Circuit Lab), UW–Madison  
**Jan 2018** External Reviewer for DAC 2018  
**Seq 2017** Research Assistant in WiCIL

## NON-ACADEMIC ACTIVITY

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**Nov 2011** Campus Computer Gaming Champion of DOTA in Fudan University  
**May 2010** Volunteer for EXPO 2010 in Shanghai  
**Mar 2010** Excellent Student Leader for Excellent Student Union Leader of Fudan University  
**Sep 2009** Minister of Sports in the Student Union of Fudan University  
**2009,10,12** Campus Basketball Champion in Zhangjiang Campus of Fudan University  
**May 2008** Volunteer for helping disabled students of Guanxin School in Shanghai