Education

University of Notre Dame

Ph.D. in Computer Science & Engineering

Exp. April 2024 | Notre Dame, IN GPA: 4.0

Rochester Institute of Technology

M.S. in Computer Engineering May 2019 | Rochester, NY GPA: 4.0 | magna cum laude

B.S. in Computer Engineering

May 2019 | Rochester, NY GPA: 3.7 | magna cum laude

Skills

AI & ML

Explainable AI • Deep Learning • Computer Vision • Machine Learning • Trustworthy AI • Responsible AI • Interpretable ML • Convolutional Neural Networks (CNNs)

Deep Neural Networks (DNNs)
 Large Language Models (LLMs)

Generative AI • Transformers • Image Processing Algorithms

Programming

Python • C/C++ • LATEX • Bash/ Shell • Julia • Java • Verilog • VHDL • JS/HTML/CSS

Software

PyTorch • TensorFlow • Keras • scikit-learn • OpenCV • SymPy • Git • SVN • Docker • Singularity • Matplotlib/Seaborn • MATLAB • ray • Django • ROS • SQL • Azure • AWS

OS

Arch Linux • Ubuntu/Debian • CentOS • NixOS • Linux • Windows

Other

System admin • Project management • Web dev

Links

- 🗗 GitHub | @ craymichael
- ♂ StackOverflow | @ craymichael
- ☑ LinkedIn | @ craymichael

Google Scholar

Service

- Computer Vision Foundation
- NeurIPS

Research Experience

University of Notre Dame | Graduate Research Assistant

August 2019 - Present | Notre Dame, IN

- Researched and implemented an intrinsically interpretable neural network architecture to open the AI black box that is compatible with vision, language, and tabular data. My patent-pending approach based on prototypical part neural networks quantifiably increased the interpretability of state-of-the-art convolutional and transformer neural networks by up to 25× on fine-grained image classification tasks. This research is under review.
- Proposed a highly effective **defense for explainers against adversarial attacks** to identify malicious auditees at an **80% identification rate** and recover faithful explanations with **99% fidelity**. The results were presented at my talk at **AAAI'23**.
- Uncovered the **infidelity of post hoc explainable AI (XAI)** methods through rigorous research and analysis, exposing the limitations of black box interpretation in data-driven decision-making processes. Surprisingly, **popular XAI methods show up to a 70% accuracy decrease** on both synthetic and real-world scenarios. The results will be presented at a conference this year.
- Developed an efficient **open-source** symbolic framework in **Python** that enables researchers to study feature attribution, interaction effects, and explanations of arbitrarily complex scientific or data-driven models.
- Computer Vision Research Lab 2 member and advised by Prof. Walter J. Scheirer 2.

Hewlett Packard Enterprise Labs | Research Associate Intern

May 2023 - Present | Milpitas, CA

- Developed a **3D** image to image convolutional neural network surrogate for a computational fluid dynamics solver to improve data center sustainability, achieving **2,000**× **speedup**. The surrogate is combined with online reinforcement learning for the optimization of the **carbon footprint** of data centers.
- Researched and developed **reinforcement learning** methods for the evaluation and enhancement of **natural adversarial robustness** in deep neural networks for vision. The framework identifies distortion-specific errors in models **up to 60% better** than the prior state-of-the-art.

Mitsubishi Electric Research Lab | PhD Research Intern

June 2022 - September 2022 | Boston, MA

- Conducted original research on intrinsically **human-interpretable AI** for (weakly supervised) vision tasks under supervision of **Dr. Mike Jones C** that led to a **patent** submission.
- Uncovered and **mitigated a fundamental shortcoming** of prototypical part neural networks (often applied to **high-stakes domains** including biomedical imaging) that can produce **highly misleading explanations** the **solution C**² that I researched and developed **improves inter-pretability by up to 25**×.
- Helped run a reading group for the state-of-the-art in computer vision that comprised over 20 researchers.

Lawrence Livermore National Lab | Graduate Student Intern

May 2021 - August 2021 | Remote

- Proposed a novel algorithm (XNAS) based on representation disentanglement for the optimization of the accuracy-interpretability Pareto front via multi-objective neural architecture search (NAS). XNAS discovers architectures that are 3× better at error detection and 10% better calibrated. Presented the research at AutoML'23.
- Scaled XNAS to a cluster of >100 nodes using Ray and asynchronous algorithm design with near-linear speedup.
- Employed a deep learning **object detection pipeline** (MaskRCNN and YOLO) for asteroids in Zwicky Transient Facility (ZTF) difference image data with detection **accuracy** >**90%**.

Neuromorphic Al Lab | Research Scientist

August 2019 - May 2021 | University of Texas at San Antonio, San Antonio, TX

Maintained cross-team collaborations with epidemiologists and demographers in the epidemiological modeling of COVID-19 infectious spread. Researched and developed a recurrent neural-compartmental epidemiological model for forecasting COVID-19 spread in

- IEEE/CVF CVPR
- IEEE/CVF ICCV
- IEEE/CVF WACV
- IEEE Access
- IEEE Transactions on Computers
- Czech Science Foundation
- IEEE TNNLS

real-time. The research was presented at IJCAI'20.

- Developed and **deployed a real-time online dashboard to production** for Texas state showcasing case data and forecasts.
- Maintained a **cross-team collaboration** with medical professionals in an IRB-approved study of Alzheimer's patients in underrepresented communities in Texas. Researched methods for **deep learning applications to Alzheimer's detection** with EEG data rather than MRI due to cost and accessibility.

Neuromorphic Al Lab | Graduate Research Assistant

January 2018 - August 2019 | Rochester Institute of Technology, Rochester, NY

- The culmination of these works won me the RIT Outstanding M.S. Thesis Award for my thesis, "Towards Lightweight AI: Leveraging Stochasticity, Quantization, and Tensorization for Forecasting."
- Developed the **register-transfer-level (RTL) design** of generic bit width multiply-andaccumulate (MAC) components for the posit numerical system. Researched the accuracyenergy-latency trade-off of **model compression** via **low-precision arithmetic** and softwarehardware co-design and development of a neural network on FPGAs. The implementation achieved up to **10% less accuracy degradation** than standard IEEE floating point with comparable power and latency. The now well-cited papers were presented and published at the venues **DATE'19 and CoNGA'19**.
- Improved compute and memory efficiency of neural networks for time series forecasting upwards of 95% in size and training speed using randomness and model compression for resource-constrained devices.
- Researched the **Pareto front of design characteristics** of echo state networks for forecasting of spatiotemporal sequences with **state-of-the-art results** on forecasting tasks, (e.g., beating the previous Piano-midi.de 1-step ahead forecasting best by 1%).

Publications

† Z. Carmichael, S. Lohit, A. Cheerian, M. Jones, W. J. Scheirer. "Pixel-Grounded Prototypical Part Networks." In Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision, Waikoloa, Hawaii, USA, 2024. arXiv ☑

† S. Sarkar, A. Ramesh Babu, S. Mousavi, **Z. Carmichael**, V. Gundecha, S. Ghorbanpour, R. Luna Gutierrez, A. Guillen, A. Naug. "Benchmark Generation Framework with Custom Distortions for Image Classifier Robustness." In Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision, Waikoloa, Hawaii, USA, 2024. arXiv 🗗

†§‡**Z. Carmichael**, W. J. Scheirer. "**Unfooling Perturbation-Based Post Hoc Explainers**." In *Proceedings of the AAAI Conference on Artificial Intelligence*, Washington D.C., USA, 2023. AAAI Press ☑ | arXiv ☑

Z. Carmichael, W. J. Scheirer. "How Well Do Feature-Additive Explainers Explain Feature-Additive Predictors?." *Preprint* (Under Review), –, 2023. arXiv

S. Sarkar, A. Naug, **Z. Carmichael**, A Guillen, V. Gundecha, R. Luna, L. D. Kashyap, S. Ghorbanpour, D. Markovikj, S. Mousavi, A. Ramesh-Babu. "**CFD Surrogates for Data Center Sustainability Using 3D Convolutional Models**." *Preprint* (Under Review), –, 2023. arXiv C^{*}

†§‡**Z. Carmichael**, T. Moon, S. A. Jacobs. "**Learning Debuggable Models Through Multi-Objective Neural Architecture Search**." International Conference on Automated Machine Learning (AutoML) Workshop, Potsdam/Berlin, Germany, 2023. arXiv ⊡

S. J. Abraham, K. D. G. Maduranga, J. Kinnison, **Z. Carmichael**, J. D. Hauenstein, W. J. Scheirer. "HomOpt: A Homotopy-Based Hyperparameter Optimization Method." *Preprint* (Under Review), -, 2023. arXiv C^{*}

†§‡ W. Theisen, D. Gonzalez, **Z. Carmichael**, T. Weninger, W. J. Scheirer. "**Motif Mining: Finding** and Summarizing Remixed Image Content." In *Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision (WACV)*, Waikoloa, Hawaii, USA, 2023. arXiv 🗗

†‡ J. Takeshita, Z. Carmichael, R. Karl, T. Jung. "TERSE: Tiny Encryptions and Really Speedy Execution for Post-Quantum Private Stream Aggregation." In EAI International Conference on Security and Privacy in Communication Networks (SecureComm), Kansas City, USA, 2022. IACR Cryptology ePrint Archive

†§ S. Abraham, Z. Carmichael, S. Banerjee, R. VidalMata, A. Agrawal, M. N. Al Islam, W. Scheirer, J. Cleland-Huang. "Adaptive Autonomy in Human-on-the-Loop Vision-Based Robotics Systems." In 1st Workshop on Al Engineering – Software Engineering for Al (WAIN'21), Remote, 2021. arXiv C

†‡ H. Langroudi, V. Karia, Z. Carmichael, A. Zyarah, T. Pandit, J. L. Gustafson, D. Kudithipudi. "ALPS: Adaptive Quantization of Deep Neural Networks With GeneraLized PositS." In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops, Remote, 2021. CVF Open Access ☑

† N. Soures, D. Chambers, **Z. Carmichael**, A. Daram, D. P. Shah, K. Clark, L. Potter, D. Kudithipudi. **"SIRNet: Understanding Social Distancing Measures with Hybrid Neural Network Model for COVID-19 Infectious Spread**." In Proceedings of the International Joint Conference on Artificial Intelligence (IJCAI) Disease Computational Modeling Workshop, Remote, 2020. IJCAI DCM C | arXiv (out-of-date) C

‡ —. "—." In Proceedings of the International Conference on Machine Learning (ICML) Machine Learning for Global Health Workshop, Remote, 2020. Poster ☑

†§**Z. Carmichael**, D. Kudithipudi. "**Stochastic Tucker-Decomposed Recurrent Neural Networks** for Forecasting." In *IEEE Global Conference on Signal and Information Processing (GlobalSIP 2019)*, Ottawa, Canada, 2019. IEEE Xplore® ☑

†§Z. Carmichael. "Towards Lightweight Al: Leveraging Stochasticity, Quantization, and Tensorization for Forecasting." Master's Thesis (Won the 2019 RIT Outstanding Master's Thesis Award), Department of Computer Engineering, Rochester Institute of Technology, 2019. RIT Scholar Works ₽

†§**Z. Carmichael**, H. F. Langroudi, C. Khazanov, J. Lillie, J. L. Gustafson, D. Kudithipudi. "**Deep Positron: A Deep Neural Network Using the Posit Number System**." In *Proceedings of the IEEE Conference and Exhibition on Design, Automation and Test in Europe (DATE),* Florence, Italy, March 25-29, 2019. IEEE, 1421–1426. IEEE Xplore® C | arXiv C²

†§**Z. Carmichael**, H. F. Langroudi, C. Khazanov, J. Lillie, J. L. Gustafson, D. Kudithipudi. "**Performance-Efficiency Trade-off of Low-Precision Numerical Formats in Deep Neural Networks**." In *Proceedings of the ACM Conference for Next Generation Arithmetic (CoNGA)*, Singapore, 2019. ACM DLC | arXivC

H. F. Langroudi, Z. Carmichael, J. L. Gustafson, D. Kudithipudi. "*Cheetah*: Mixed Low-Precision Hardware & Software Co-Design Framework for DNNs on the Edge." *arXiv*, Preprint, 2019. arXiv C^{*}

†§H. F. Langroudi, **Z. Carmichael**, J. L. Gustafson, D. Kudithipudi. "**PositNN Framework: Tapered Precision Deep Learning Inference for the Edge**." In *Proceedings of the Twelfth IEEE Space Computing Conference (SCC 2019* ℃), Pasadena, CA, July 30-August 1, 2019. IEEE, 53–59. IEEE Xplore® ℃

†§ Z. Carmichael, H. Syed, D. Kudithipudi. "Analysis of Wide and Deep Echo State Networks for Multiscale Spatiotemporal Time Series Forecasting." In ACM International Conference Proceedings Series (ICPS) of the Neuro Inspired Computational Elements (NICE) Workshop, Albany, NY, 2019. ACM DLC² | arXivC²

†§ Z. Carmichael, B. Glasstone, F. Cwitkowitz, K. Alexopoulos, R. Relyea, R. Ptucha. "Autonomous Navigation Using Localization Priors, Sensor Fusion, and Terrain Classification." In Proceedings of IS&T International Symposium on Electronic Imaging: Autonomous Vehicles and Machines, San Francisco, CA, 2019. Ingenta Connect ⊡

†**‡Z. Carmichael**, H. Syed, S. Burtner, D. Kudithipudi. "**Mod-DeepESN: Modular Deep Echo State Network**." In Annual Conference on Cognitive Computational Neuroscience, Philadelphia, PA, 2018. CCN (out-of-date) ☑ | arXiv ☑

Other Publications

Z. Carmichael. "Demystifying ChatGPT and Other Large Language Models." Digital Spirits Substack, Online, 2023. DigitalSpirits

Z. Carmichael. "Noncompliance in Algorithmic Audits and Defending Auditors." *Medium*, Online, 2023. Medium ☑

Grants & Fellowships

NSF Graduate Fellowships Research Program (GRFP) Honorable Mention 2020

University of Notre Dame Jack and Mary Ann Remick Fellowship in Engineering 2019-2024

University of Notre Dame Kilgallon Family Graduate Fellowship 2019-2024

Honors & Awards

RIT Outstanding M.S. Thesis Award 2019

Thesis: "Towards Lightweight AI: Leveraging Stochasticity, Quantization, and Tensorization for Forecasting"

UTSA Best Poster: Fundamental Research in AI (Ph.D.) 2019

Poster: "Cheetah: Mixed Low-Precision Hardware & Software Co-Design Framework for DNNs on the Edge"

RIT KGCOE Dean's List 2014-2019

RIT Presidential Scholarship 2014-2019

RIT BS/MS Tuition Award 2014-2019

RIT Excellence in Computing 2014

Projects

Black & White Video Enhancement: Amahl & the Night Visitors 2022

video super-resolution • video colorization • video denoising • computer vision • deep learning

NFL Betting App with Betting Al 2020

deep learning ${\scriptstyle \bullet}$ probability ${\scriptstyle \bullet}$ web development ${\scriptstyle \bullet}$ databases

CNNs for Loop-Closure Detection in vSLAM Systems 2018-2019

SLAM • autonomous driving • convolutional neural networks

Autonomous Golf Cart - "Tiger Taxi" 2018

SLAM • autonomous driving • convolutional neural networks • ROS • timed-elastic-band navigation and control

Segmentation of Histopathological Images Using U-Net 2018

biomedical imaging ${\, \bullet \,}$ convolutional neural networks ${\, \bullet \,}$ image to image translation ${\, \bullet \,}$ image segmentation ${\, \bullet \,}$ morphological operations

Experience

Computer Vision Foundation | Web Manager

September 2019 - Present | Remote

- Position funds my PhD
- Rewrote, audited, & actively maintain CVF Open Access 12 to better serve papers, talks, posters, & other open content from the CVPR, ICCV, ECCV, & WACV conferences to 500,000+ monthly visitors
- Automated synchronization of CVF COVE
 computer vision datasets & arXiv erratum retrieval with Open Access
- Discovered & mitigated several SQL security vulnerabilities

University of Notre Dame | Graduate Teaching Assistant

August 2019 - May 2020 | Notre Dame, IN

- Courses: Advanced Topics in Machine Learning (ML) (20+ students | Graduate CS); Theory of Computing (30+ students | Upper-level undergraduate CS)
- Taught students core CS & ML concepts in office hours, scoped assignments, held review sessions, & graded exams

Plexus Corp. | Digital Engineering Intern

June 2017 - August 2017 | Raleigh, NC

• Carried out RTL design of FPGA-agnostic module for evaluation of FPGA cooling systems,

validated all test cases with digital engineering team

• Developed embedded software for a battery testing unit using the FRDM-K64F dev board, validated design & integration with mechanical, electrical, & software teams

CUBRC, Inc. | Research/Software Engineering Intern

June 2016 - December 2016 | Cheektowaga, NY

- Developed a machine learning framework to model surgery risk, patient mortality, & other analytics using TensorFlow & scikit-learn with automatic model search & hyperparameter optimization
- Worked with customers in the design of electronic health record-unifying database & interface

Membership

Institute of Electrical and Electronics Engineers (IEEE) Student 2018 - Now Tau Beta Pi – The Engineering Honor Society (TBII) 2018 - Now The National Society of Leadership and Success ($\Sigma A \Pi$) 2018 - Now Sigma Xi Nomination ($\Sigma \Xi$) 2020