Hai Duong

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EDUCATION

George Mason University, Ph.D., Computer Science 2022 - now

- Advisor: Prof. ThanhVu Nguyen
- Topic: Formal Verification of Deep Neural Networks

Hanoi University of Science and Technology (HUST), M.S., Electrical Engineering 2019 - 2021

- Advisor: Prof. Quoc Cuong Nguyen
- Topic: Deep Learning-based Speech Processing

Hanoi University of Science and Technology, B.E., Electrical Engineering 2014 - 2019

AWARDS

- NeuralSAT ranked 2-nd at VNN-COMP'24.
- NeuralSAT received New Participant Award at VNN-COMP'23.
- NeuralSAT ranked 4-th at VNN-COMP'23.
- HUST Outstanding Undergraduate Award 2015, 2016, 2017, 2018 (top 5% of School of Electrical Engineering).

PUBLICATIONS

- **Bold conference or journal names**: full technical papers at top conferences or journals.

Published

1. *Hai Duong*; ThanhVu Nguyen; Matthew B. Dwyer. NeuralSAT: A High-Performance Verification Tool for Deep Neural Networks (to appear)., In: **Computer Aided Verification (CAV)**, to appear, 2025.
2. *Hai Duong*; Dong Xu; ThanhVu Nguyen; Matthew B. Dwyer. Harnessing Neuron Stability to Improve DNN Verification., In: **Foundations of Software Engineering (FSE)**, Article 39, pp. 859-881, 2024.
3. Dong Xu; Nusrat Jahan Mozumder; *Hai Duong*; Matthew B. Dwyer. Training for Verification: Increasing Neuron Stability to Scale DNN Verification., In: **Tools and Algorithms for the Construction and Analysis of Systems (TACAS)**, pp. 24-44, 2024.
4. ThanhVu Nguyen; KimHao Nguyen; *Hai Duong*. SymInfer: Inferring Numerical Invariants using Symbolic States., In: International Conference on Software Engineering - Tool Demo (ICSE-Demo), pp. 197–201, 2022.
5. Huu Binh Nguyen; *Hai Duong*; Tien Dat Bui; Ngoc Chau Hoang; Quoc Cuong Nguyen. Multi-Channel Speech Enhancement using a Minimum Variance Distortionless Response Beamformer based on Graph Convolutional Network., In: International Journal of Advanced Computer Science and Applications (IJACSA), Volume 13 Issue 10, pp. 739-747, 2022.
6. Thanh Dat Nguyen, Thanh Le Cong, Duc Minh Luong, *Hai Duong*, Xuan Bach D. Le, David Lo and Quyet Thang Huynh. FFL: Fine grained Fault Localization for Student Programs via Syntactic and Semantic Reasoning., In: International Conference on Software Maintenance and Evolution (ICSME), pp. 151-162, 2022.
7. Huu Binh Nguyen, *Hai Duong*, Anh Xuan Tran Thi, and Quoc Cuong Nguyen. Efficient Keyword Spotting System using Deformable Convolutional Network., In: IETE Journal of Research, pp. 4196-4204, 2021.

EXPERIENCE

Research Assistant 2022 - now

DynaROARS Lab, George Mason University, USA *Fairfax, VA*

- Deep Neural Network Verification: Developed a verification tool, NeuralSAT, by adapting Boolean Abstraction, Boolean Constraint Propagation, Conflict Clause Learning, Restart heuristic, etc., from SAT solving with the Abstraction Interpretation, which aims to formally verify safety and robustness properties of DNNs. Participated

in the annual competition VNN-COMPs, ranked 4-th at VNN-COMP'23 and 2-nd at VNN-COMP'24. Published a paper at FSE'24 by proposing neuron stabilization optimization allowing NeuralSAT to outperform state-of-the-art verifiers on challenging problems.

- DNN Proofs Generation and Checking: Identified commonalities in the algorithmic approaches taken by DNN verification tools to define a verifier independent proof format - APTP. Designed an algorithm for checking those proofs that is proven correct and optimized to enable scalable checking. Tool significantly outperforms prior work on a benchmark of 16 neural networks and 400 DNNV problems, and that it is robust to variation in APTP proof structure arising from different DNN verification tools. Moreover, when tool detects unsound bugs from verifier results, it can formulate an optimization problem to achieve these bugs in state-of-the-art DNN verifiers.
- Compositional Verification of DNNs: Proposed an assume-guarantee compositional framework, CoVeNN, that is parameterized by an underlying verifier to generate a sequence of verification sub-problems to address this challenge. CoVeNN presents an iterative refinement-based strategy for computing assumptions that allow sub-problems to retain sufficient accuracy to prove the original problem. An evaluation using 6 neural networks and 120 property specifications demonstrates that CoVeNN can verify 6.5 times more problems than state-of-the-art verifiers.
- Decision Heuristic for DNN Verification: Proposed DRL-based branching strategies based on learning algorithms without significantly increasing branching costs. DRL has capability of learning long-term rewards that allows proposed heuristic to avoid myopic selections during the search. We trained our models on small and simply networks and made them generalized for different types of networks, such as CNNs, ResNets, etc.
- Contribute to tool building for the SymInfer paper, published at ICSE'22 demo track.

Research Assistant 2021 - 2022
BachLe's Lab, University of Melbourne, Australia *Remote*

- Worked on Graph-based source code modeling, explanation techniques on graph, and conduct experiments for a published paper at ICSME'22.

Research Assistant 2019 - 2021
Sensor Lab, Hanoi University of Science and Technology, Vietnam *Hanoi, VN*

- Adopted Deformable Convolution in the small foot-print Keyword Spotting task, resulting in a published article at IETE'21 journal. Improved inferencing speed 5 times by implementing DNN executor in FPGA.
- Developed multi-channel speech enhancement system using graph-based neural beamforming, published an article at IJACSA'22 journal.

TECHNICAL SKILLS

- **Languages:** Python, Java, C/C++.
- **Frameworks and tools:** PyTorch, HuggingFace, Pytorch Lightning, Scikit-learn, Numpy, Git, Docker, SQLite

MISCS

- Contributed to proposal: *CAREER: NeuralSAT: A Constraint-Solving Framework for Verifying Deep Neural Networks. NSF 2238133. 8/1/2023–7/31/2028, $510,509. NSF (funded)*.
- Contributed to proposals: *Amazon Research Award (Automated Reasoning): Scalable and Precise DNN Constraint Solving with Abstraction and Conflict Clause Learning. 2023, $50,000 unrestricted gift. Amazon (funded)*.
- Helped review papers at conferences: ISSTA'23, PLDI'24, OOPSLA'24.