

Ayoosh Bansal

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Education

University of Illinois Urbana-Champaign

Urbana, Illinois, USA

PhD in Computer Science, Advised by Prof. Lui Sha

Aug 2017 - Aug 2024

Dissertation title : Safe and Secure Autonomous Vehicles

Committee : Lui Raymond Sha, Marco Caccamo, Adam Bates Yuile, Parameswaran Ramanathan

Research Topics : System Architecture, Safe use of AI, Autonomous Vehicles, Cyber-Physical Systems, Real-Time Systems, Functional Safety, Temporal Safety, System Security, Computer Architecture

University of Wisconsin-Madison

Madison, Wisconsin, USA

Master of Science in Electrical Engineering, GPA 4/4

Sep 2013 - May 2015

Courses: Real-Time Systems, Operating Systems, Computer Architecture, Compiler Optimization

Birla Institute of Technology and Science Pilani, India

Pilani, Rajasthan, India

Bachelor of Engineering (Hons.) Electrical and Electronics, CGPA 8.6/10

Aug 2006 - Jul 2010

Research Experience

Cyber Physical Systems Integration Lab, UIUC

Urbana, Illinois, USA

Graduate Research Assistant

Aug 2017 – Aug 2024

- Designed holistic system solutions for enhancing functional safety, bolstering system security, and refining temporal predictability in cyber-physical and real-time systems, with a focus on autonomous ground and aerial vehicles. A presentation summarizing the research achievements is linked [here](#).
- Pioneered verifiable perception safety in autonomous ground vehicles by developing *Perception Simplex*, a system architecture that provides verifiable obstacle detection and deterministic collision avoidance within the operational design domain. The safety guarantees were proven analytically and validated using open-source industrial simulation frameworks.
- Adapted *Perception Simplex* to aerial vehicles, while improving its performance by closely integrating low-level control to dynamically confirm the control capabilities of the system, rather than assume static worst-case.
- Recognizing the lack of context-aware metrics for object detection in autonomous driving, created *Risk Ranked Recall*. This metric differentiates between objects based on their safety impacts.
- As part of a collaborative effort, including industrial partners from NASA, developed a photorealistic software-in-the-loop simulation framework for autonomous air taxis.
- To bring security auditing to real-time systems, created *Ellipsis*. Harnessing the inherent predictability of behaviors in real-time applications, *Ellipsis* optimizes Linux Audit for real-time applications. *Ellipsis* all but eliminates the possibility of audit event loss during typical operation and significantly curtails auditing data volume (> 90%) while preserving security-relevant information.
- Introduced a new memory type, *Inner Non-Cacheable*, *Outer Cacheable*, empowering real-time applications to bypass cache coherence mechanisms and mitigate memory access latency variability, selectively for shared data, with no impact on private data. Prototype implementation on Linux Kernel and Gem5 simulator, yielded 52% reduced worst-case latency and negligible impact on performance.
- Designed a scratchpad based cooperative execution model between processor cores and hardware accelerators, achieving similar energy and latency efficiency as monolithic fixed function hardware accelerators, while supporting flexible functions.
- Helped design security-aware task scheduling for real-time applications, minimizing the impacts of posterior schedule based class of attacks on real-time systems.
- Helped develop an input prioritization schemes for object detection neural networks, overcoming the priority inversion inherent to such solutions.
- Ongoing work on *Synergistic Simplex* system architecture that harnesses cooperation among safety- and mission-critical elements to enhance the safety and performance of autonomous ground and aerial vehicles.

University of Wisconsin-Madison

Madison, Wisconsin, USA

Graduate Research Assistant

Sep 2014 – May 2015

- Conceptualized thermal capacity of computational systems, analogous to computational capacity. Devised software scheduling policies that ensure the processor core temperature can be kept below a threshold. Thermal capacity trivializes thermal aware scheduling complexity and can schedule both periodic and aperiodic tasks.
- Studied emerging distributed electricity markets and developed a Simulink and NS3 co-simulation framework for systems containing electrical and network elements.

Graduate Student

Sep 2013 – May 2014

- Developed software-assisted bias-free branch predictor, a compiler assisted improvement to history based branch predictors. Strongly biased branch instructions are marked by the compiler with branch direction. Marked branch instructions are predicted as marked and not entered in branch history. Reduced branch misprediction rate by 0.35% for SPEC CPU 2006 benchmarks on GEM5 simulator.
- Conducted an analysis of solid-state storage devices, focusing on compatibility with existing file systems and the consistency features of the drive to protect against loss of cached writes. Eliminating write batching improved varmail benchmark iops by 3.6%. Developed faster special case checksums using Deterministic Zero after Trim feature. Implemented as an improvement to Optimistic Crash Consistency file system, Improving iops by 4.1%.
- Implemented a configurable Neural Network Processing Unit (NPU) on a Virtex-5 FPGA, capable of accelerating different algorithms by running multilayer perceptron neural networks on the NPU.

Research Interests

My primary research interest is to develop system architectures that leverage the wonderful capabilities of machine learning, while providing verifiable mitigation of unavoidable faults in learning-based solutions. Such system design is crucial for safety-critical cyber-physical systems that depend on learning-based solutions for safety-critical tasks. Applying this system design to solve the safety challenges in autonomous ground and aerial vehicles is the focus of my current research work.

Professional Experience

NVIDIA

Santa Clara

Automotive System Software Intern

May 2020 – Aug 2020

- Engineered a hypervisor-level latency analysis system aimed at optimizing applications with stringent latency requirements.

Automotive System Software Intern

Jun 2018 – Aug 2018

- Analysed latency variability stemming from processor architecture and helped verify proposed solutions.

System Software Engineer

Jul 2015 – Jul 2017

- Developed device drivers to manage memory bandwidth allocations and participated in kernel bring-up on Tegra Parker.
- Developed the infrastructure to deploy Linux Kernel on the full-chip simulation platform for Tegra Xavier.
- Successfully led a cross-organizational effort to integrate the new full-chip simulation platform with a new regression testing infrastructure.
- Mentored an internship project which overhauled the simulator software startup process to create a seamless silicon-like flow.

NVIDIA

Beaverton

System Software Intern

May 2014 – Aug 2014

- Completed various projects to enhance Tegra full chip simulation environment. As the final project enabled DMA access between simulator and physical IO devices. Snooped kernel requests to the simulated IOMMU to set up address translations via the Linux VFIO framework.

NetApp

Bangalore

Member of Technical Staff II, NFS Server Development

May 2012 – Jul 2013

- A rich learning experience, specifically in Network File system (NFS) protocol, File Systems, Multi-Processor Programming, Networking, Distributed Systems, High Availability Clustering Systems, development in Unix environment, Security protocols (Kerberos, SSL), Debugging and Software Development Cycle.

Member of Technical Staff I, NFS Server Sustainance

Jun 2011 – Apr 2012

- As part of a customer response team, helped ensure timely resolution of customer issues in NetApp's Network File System (NFS) server.
- In a team of 3, conceptualized an invention optimizing stale mount points handling within NFS server implementations, resulting in a monetary award.

Member of Technical Staff I, CIFS Server Quality Assurance

Jul 2010 – Jun 2011

- Ensure high quality of NetApp's Common Internet File System (CIFS) server. Helped verify multiple releases, train outsource partners and mentor interns.

Broadcom

Bangalore

Intern, Bluetooth Firmware Team

Jan 2010 – Jun 2010

- Developed a Perl based Bluetooth device emulator, capable of emulating different Bluetooth Human Interface Devices.

Teaching

Department of Computer Science, University of Illinois at Urbana-Champaign

Urbana

Graduate Teaching Assistant

Jan 2020 – May 2020

- Conducted labs and initiated efforts to modernize Embedded System Lab projects. A unique challenge was the switch to remote working due to COVID-19 shutdowns.

Department of Physics, University of Wisconsin-Madison

Urbana

Graduate Teaching Assistant

Aug 2013 – May 2014

- Conducted labs, tutorials and consultations. Helped develop a new instruction format which focused on inculcating intuition and visualization of classical mechanics.

Research Sponsorship

- Authored an NSF CPS proposal aimed at advancing autonomous vehicle safety, as a virtual Co-PI, with PI Prof. Lui Sha and Co-PI Prof. Yanbing Mao. Proposal is currently being reviewed.
- Helped author Virtual Sully proposal (NSF CNS-1932529), with a focus on fault tolerant architecture for autonomous UAVs.

Awards

- 2020 Best Paper, IEEE Real-Time Systems Symposium
- 2017 Saburo Muroga Endowed Fellowship, University of Illinois Urbana-Champaign
- 2015 Graduate Academic Achievement Award, ISS, University of Wisconsin-Madison
- 2015 Best Student Paper, International Conference on VLSI Design

Presentations

- Jan 2024 Synergistic Perception and Control Simplex for Verifiable Safe Vertical Landing, AIAA SCITECH 2024 Forum
- Nov 2023 Certifiably Safe and Robust Perception for Learning-enabled Autonomy, AVIATE Center, NASA ULI
- Nov 2022 Verifiable obstacle detection, IEEE 33rd International Symposium on Software Reliability Engineering (ISSRE)
- Jan 2015 Thermal extension of the total bandwidth server, 28th International Conference on VLSI Design

Publications

Perception simplex: Verifiable collision avoidance in autonomous vehicles amidst obstacle detection faults

Ayoosh Bansal, Hunmin Kim, Simon Yu, Bo Li, Naira Hovakimyan, Marco Caccamo, Lui Sha

Software Testing, Verification and Reliability (2024) e1879. Wiley Online Library, 2024

Synergistic Perception and Control Simplex for Verifiable Safe Vertical Landing

Ayoosh Bansal, Yang Zhao, James Zhu, Sheng Cheng, Yuliang Gu, Hyung Jin Yoon, Hunmin Kim, Naira Hovakimyan, Lui R Sha

AIAA SCITECH 2024 Forum, 2024

Taming Algorithmic Priority Inversion in Mission-Critical Perception Pipelines

Shengzhong Liu, Shuochao Yao, Xinzhe Fu, Rohan Tabish, Simon Yu, **Ayoosh Bansal**, Heechul Yun, Lui Sha, Tarek Abdelzaher

Communications of the ACM 67.2 (2024) pp. 110–117. ACM New York, NY, USA, 2024

System Auditing for Real-Time Systems

Ayoosh Bansal, Anant Kandikuppa, Monowar Hasan, Chien-Ying Chen, Adam Bates, Sibin Mohan

ACM Transactions on Privacy and Security (2023). ACM, 2023

SchedGuard++: Protecting against Schedule Leaks Using Linux Containers on Multi-Core Processors

Jiyang Chen, Tomasz Kloda, Rohan Tabish, **Ayoosh Bansal**, Chien-Ying Chen, Bo Liu, Sibin Mohan, Marco Caccamo, Lui Sha

ACM Transactions on Cyber-Physical Systems 7.1 (2023) pp. 1–25. ACM New York, NY, 2023

Towards Efficient Auditing for Real-Time Systems

Ayoosh Bansal, Anant Kandikuppa, Chien-Ying Chen, Monowar Hasan, Adam Bates, Sibin Mohan

European Symposium on Research in Computer Security, 2022

Verifiable obstacle detection

Ayoosh Bansal, Hunmin Kim, Simon Yu, Bo Li, Naira Hovakimyan, Marco Caccamo, Lui Sha

2022 IEEE 33rd International Symposium on Software Reliability Engineering (ISSRE), 2022

Risk Ranked Recall: Collision Safety Metric for Object Detection Systems in Autonomous Vehicles

Ayoosh Bansal, Jayati Singh, Micaela Verucchi, Marco Caccamo, Lui Sha

2021 10th Mediterranean Conference on Embedded Computing (MECO), 2021

SchedGuard: Protecting against Schedule Leaks Using Linux Containers

Jiyang Chen, Tomasz Kloda, **Ayoosh Bansal**, Rohan Tabish, Chien-Ying Chen, Bo Liu, Sibin Mohan, Marco Caccamo, Lui Sha
27th IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS'21), 2021

Reconciling predictability and coherent caching

Ayoosh Bansal, Jayati Singh, Yifan Hao, Jen-Yang Wen, Renato Mancuso, Marco Caccamo
2020 9th Mediterranean Conference on Embedded Computing (MECO), 2020

On removing algorithmic priority inversion from mission-critical machine inference pipelines

Shengzhong Liu, Shuochao Yao, Xinzhe Fu, Rohan Tabish, Simon Yu, **Ayoosh Bansal**, Heechul Yun, Lui Sha, Tarek Abdelzaher
2020 IEEE Real-Time Systems Symposium (RTSS), 2020

Sidebar: Scratchpad Based Communication Between CPUs and Accelerators

Ayoosh Bansal, Chance Coats, Evan Lissoos, Benjamin Schreiber
arXiv preprint arXiv:1910.10794 (2019). 2019

Evaluating the memory subsystem of a configurable heterogeneous mpsoC

Ayoosh Bansal, Rohan Tabish, Giovanni Gracioli, Renato Mancuso, Rodolfo Pellizzoni, Marco Caccamo
Workshop on Operating Systems Platforms for Embedded Real-Time Applications (OSPRT), 2018

Thermal extension of the total bandwidth server

Rehan Ahmed, **Ayoosh Bansal**, Bhuvana Kakunoori, Parameswaran Ramanathan, Kewal K Saluja
2015 28th International Conference on VLSI Design, 2015