Ayoosh Bansal

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Education

University of Illinois Urbana-Champaign   Urbana, Illinois, USA
PhD in Computer Science, Advised by Prof. Lui Sha, GPA 4/4   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, Autonomous Ground & Aerial Vehicles, Safe use of AI, Cyber-Physical Systems
                     Functional Safety, Real-Time Systems, 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
Postdoctoral Research Associate   Oct 2024 – Present

- Designing *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.
- As part of a collaborative effort, including industrial partners from NASA, designing and developing AirTaxiSim, a photorealistic software-in-the-loop simulation framework for autonomous air taxis.
- Using preliminary versions of AirTaxiSim, helped develop a learning data augmentation framework for perception DNN and a verification and validation framework for path planning for autonomous air taxis.

Graduate Research Assistant   Aug 2017 – Aug 2024

- Led multiple research projects, architecting 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.
- 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.

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.

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 Sustenance   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.

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

Oct 2024   Certifiably Safe and Robust Perception for Learning-enabled Autonomy, AVIATE Center, NASA ULI

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

DISSERTATION

Safe and Secure Autonomous Vehicles
    Ayoosh Bansal. University Illinois at Urbana-Champaign. 2024

JOURNAL ARTICLES

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

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

Real-time task scheduling for machine perception in intelligent cyber-physical systems
    Shengzhong Liu, Shuochao Yao, Xinzhe Fu, Huajie Shao, Rohan Tabish, Simon Yu, **Ayoosh Bansal**, Heechul Yun, Lui Sha, Tarek Abdelzaher
    IEEE Transactions on Computers 71.8 (2021) pp. 1770–1783. IEEE, 2021

CONFERENCE PROCEEDINGS

Verification and Validation of a Vision-Based Landing System for Autonomous VTOL Air Taxis
    Ayoosh Bansal*, Duo Wang*, Mikael Yeghiazaryan*, Yangge Li, Chuyuan Tao, Hyung-Jin Yoon, Prateek Arora, Christos Papachristos, Petros Voulgaris, Sayan Mitra, Lui Sha, Naira Hovakimyan
    AIAA SCITECH 2025 Forum, 2025

Bayesian Data Augmentation and Training for Perception DNN in Autonomous Aerial Vehicles
    Ashik E Rasul, Humaira Tasnim, Hyung-Jin Yoon, **Ayoosh Bansal**, Duo Wang, Naira Hovakimyan, Lui Sha, Petros Voulgaris
    AIAA SCITECH 2025 Forum, 2025

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

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

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

Workshop Proceedings

Evaluating the memory subsystem of a configurable heterogeneous mpsoc

Ayoosh Bansal, Rohan Tabish, Giovani Gracioli, Renato Mancuso, Rodolfo Pellizzoni, Marco Caccamo

Workshop on Operating Systems Platforms for Embedded Real-Time Applications (OSPERT), 2018

Preprints

Synergistic Redundancy: Towards Verifiable Safety for Autonomous Vehicles

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

arXiv preprint arXiv:2209.01710v1 (2022). 2022

Lidar cluster first and camera inference later: A new perspective towards autonomous driving

Jiyang Chen, Simon Yu, Rohan Tabish, **Ayoosh Bansal**, Shengzhong Liu, Tarek Abdelzaher, Lui Sha

arXiv preprint arXiv:2111.09799 (2021). 2021

Sidebar: Scratchpad Based Communication Between CPUs and Accelerators

Ayoosh Bansal, Chance Coats, Evan Lissoos, Benjamin Schreiber

arXiv preprint arXiv:1910.10794 (2019). 2019

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* indicates equal contribution.