TAYLOR T. JOHNSON

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BRIEF BIOGRAPHY

Dr. Taylor T. Johnson is an Assistant Professor of Computer Engineering (CmpE), Computer Science (CS), and Electrical Engineering (EE) in the Department of Electrical Engineering and Computer Science (EECS) in the School of Engineering (VUSE) at Vanderbilt University (since August 2016), where he directs the Verification and Validation for Intelligent and Trustworthy Autonomy Laboratory (VeriVITAL) and is a Senior Research Scientist in the Institute for Software Integrated Systems (ISIS). Dr. Johnson serves as the President of a medical information technology startup firm, CelerFama, Inc., and as the Chief Technology Officer (CTO) of Verivital, LLC, both of which serve for technology transfer and commercialization of his research group's results to industry. Dr. Johnson was previously an Assistant Professor of Computer Science and Engineering (CSE) at the University of Texas at Arlington (September 2013 to August 2016). Dr. Johnson earned a PhD in Electrical and Computer Engineering (ECE) from the University of Illinois at Urbana-Champaign in 2013, where he worked in the Coordinated Science Laboratory with Prof. Sayan Mitra, and earlier earned an MSc in ECE at Illinois in 2010 and a BSEE from Rice University in 2008. Dr. Johnson worked in industry for Schlumberger at various times between 2005 and 2010 developing novel embedded control systems for downhole tools. Dr. Johnson's research focus is developing formal verification techniques and software tools for cyber-physical systems (CPS). Dr. Johnson has published over 60 papers on these methods and their applications across CPS domains such as power and energy systems, aerospace and avionics systems, automotive systems, transportation systems, biotechnology, and robotics, two of which were recognized with best paper awards, from the IEEE and IFIP, respectively, and one of which was awarded an ACM Best Software Repeatability Award. Dr. Johnson's research aims to develop reliable embedded and cyber-physical systems by advancing and applying techniques and tools from formal methods, control theory, embedded systems, and software engineering. Dr. Johnson is a 2018 and 2016 recipient of the AFOSR Young Investigator Program (YIP) award, a 2015 recipient of the National Science Foundation (NSF) Computer and Information Science and Engineering (CISE) Research Initiation Initiative (CRII), and his research is / has been supported by AFRL, AFOSR, ARO, DARPA, NSF (CISE CCF/SHF, CISE CNS/CPS, ENG ECCS/EPCN), the MathWorks, NVIDIA, ONR, Toyota, and USDOT. Dr. Johnson is a member of AAAS, ACM, AIAA, IEEE, and SAE. .

EDUCATION

2013 **PhD, Electrical and Computer Engineering**, *University of Illinois at Urbana-Champaign*, Urbana, IL.
- Dissertation: *Uniform Verification of Safety for Parameterized Networks of Hybrid Automata*
- Committee: Sayan Mitra (Adviser), Tarek Abdelzaher, William H. Sanders, Mahesh Viswanathan

2010 **MSc, Electrical and Computer Engineering**, *University of Illinois at Urbana-Champaign*, Urbana, IL.
- Thesis: *Fault-Tolerant Distributed Cyber-Physical Systems: Two Case Studies*
- Adviser: Sayan Mitra

2008 **BSEE, Electrical and Computer Engineering**, *Rice University*, Houston, TX.
- Senior Project: *Sensorless Synchronous Motor Control in Downhole Tools* (with Frank Havlak and Elica Skorcheva at Rice, and Fadi Abousleiman, Farès Hantous, and Slim Besbes at Supélec, Gif-sur-Yvette, France)
- Advisers: Albert Hoefel and Peter Swinburne (Schlumberger); J.D. Wise and Fathi H. Ghorbel (Rice)

ACADEMIC AND RESEARCH POSITIONS

8/2016 – Present **Assistant Professor**, *Vanderbilt University*, Electrical Eng. and Computer Science , Nashville, TN.
- Appointments in Computer Science (CS), Computer Engineering (CmpE), and Electrical Engineering (EE).
- Research Interests: Cyber-physical systems (CPS), which encompasses the Internet of Things (IoT); Safety, security, and reliability of CPS; Formal methods and formal verification; Hybrid systems; Distributed systems; Software engineering; Real-time, networked embedded control systems and software; CPS domains such as transportation systems (aerospace and automotive), medical devices, power/energy systems, and robotics
- Director of VeriVITAL: The Verification and Validation for Intelligent and Trustworthy Autonomy Laboratory

9/2013 – 8/2016 **Assistant Professor**, *University of Texas at Arlington*, Computer Science and Eng., Arlington, TX.
- Courtesy Appointment: Electrical Engineering

5/2015-5/2016 **Adjunct Faculty**, *University of Connecticut*, UTC Institute for Advanced Systems Engineering.
- Supervised capstone projects for two teams, SE 5309: Capstone Projects for Embedded Systems.
- Taught an all online summer 2015 graduate course for UTC engineers, SE 5302: Formal Methods.

Summers 2014 and 2015 **Visiting Research Faculty**, *AFOSR Summer Faculty Fellowship Program (SFFP) and AFRL Visiting Faculty Research Program (VFRP), Information Directorate, Air Force Research Laboratory*, Rome, NY.
- Research with Steven Drager and Stanley Bak to develop formal verification methods for hybrid systems and apply them to Air Force CPS, resulting in papers [C11,C13,C14,C16,J4] and software tools [S3,S4].

8/2008 – 8/2013 **Research and Teaching Assistant**, *University of Illinois at Urbana-Champaign*, Electrical and Computer Engineering, Urbana, IL.

Summer 2011 **Visiting Graduate Researcher**, *Air Force Summer Faculty Fellowship Program, Space Vehicles Directorate, Air Force Research Laboratory*, Albuquerque, NM.
- Research with R. Scott Erwin and Prof. Sayan Mitra to develop and apply hybrid systems abstraction and verification techniques to Air Force space systems problems, particularly verification of conjunction (collision) avoidance for satellite rendezvous maneuvers, resulting in paper [C6].

STARTUP AND INDUSTRY POSITIONS

December 2017 – Present **Founder and Chief Technology Officer (CTO)**, *Verivital, LLC*, Nashville, TN.
- Research, development, commercialization, and consulting activities on verification and validation results arising from our research group, particularly formal verification for autonomous cyber-physical systems.
- Founded as a Tennessee limited liability company (LLC) (EIN: 82-4335410).

May 2017 – Present **Founder and President**, *CelerFama, Inc.*, Nashville, TN.
- Technology and business development for automating data entry for electronic health records (EHRs) and electronic medical records (EMRs) using natural language processing (NLP), based on technology transfer of patent [P2].
- Founded as a Tennessee class-C corporation (EIN: 82-1521559, DUNS: 080685653, CAGE: 7VJ22).

Summer 2010 **Intern in Electrical Engineering**, *Schlumberger Technology Corporation*, Sugar Land, TX.
- Designed, implemented, and analyzed a real-time state estimator for maximum available power produced by a turbo-alternator, used for stalling protection of a turbine in a power control loop outside already cascaded velocity and torque control loops for permanent magnet synchronous motor (PMSM) control of a pump. This work resulted in a conference publication [LC1]—that won a best paper award—and patent [P1].

Summer 2008 **Intern in Electrical Engineering**, *Etudes et Productions Schlumberger*, Clamart, France.
- Analyzed and modeled analog and mixed-signal electronics designs for correctness by hand and using computer tools like PSpice with Monte Carlo simulation.

Summer 2007 **Intern in Computer Engineering**, *Schlumberger Technology Corporation*, Sugar Land, TX.
- Implemented new features on FPGAs in VHDL used in Space Vector Pulse Width Modulation (SV-PWM) control of permanent magnet synchronous motors (PMSMs).

Summer 2006 **Intern in Computer Engineering**, *Schlumberger Technology Corporation*, Sugar Land, TX.
- Designed, implemented, tested, and documented a networked boot loader and application framework in 8051 assembly and C for a microcontroller, utilizing CAN for networking via an SPI interface to a CAN transceiver.

Summer 2005 **Intern in Computer Science**, *Schlumberger Technology Corporation*, Sugar Land, TX.
- Designed and implemented an intranet web application in PHP and Javascript (AJAX) with a SQL database backend system to gather, store, and report static analysis metrics on embedded systems source code.

AWARDS AND HONORS

10/2017 **2018 Young Investigator Research Program (YIP) Award**, Air Force Office of Scientific Research (AFOSR).
Received grant award [AG7].

8/2017 **Southeastern Conference (SEC) Faculty Travel Program Award for 2017-2018**.
Travel support to visit Dr. Dylan Shell at Texas A&M University to collaborate on distributed and swarm robotics.

4/2016 **Best Software Repeatability Evaluation Award for [C17]**, 19th ACM International Conference on Hybrid Systems: Computation and Control (HSCC), Cyber-Physical Systems Week (CPSWeek) 2016, Austria, Vienna.

2/2016 **2016 Young Investigator Research Program (YIP) Award**, Air Force Office of Scientific Research (AFOSR).
Received grant award [CG10].

6/2015 **Computer and Information Science and Engineering (CISE) Research Initiation Initiative (CRII) Award**, National Science Foundation (NSF), Computer and Information Science and Engineering (CISE).
Received grant award [AG1].

Summer 2015 **Fellow**, *Air Force Research Laboratory, Information Directorate*, Air Force Office of Scientific Research (AFOSR), Summer Faculty Fellowship Program (SFFP), Rome, NY..
Received grant award [CG3].

3/2013 **Yi-Min Wang and Pi-Yu Chung Endowed Research Award**, *Electrical and Computer Engineering, University of Illinois at Urbana-Champaign*, Urbana, IL.

3/2013 **ECE Rambus Fellowship in Electrical and Computer Engineering**, *Electrical and Computer Engineering, University of Illinois at Urbana-Champaign*, Urbana, IL.

6/2012 **Best Overall Paper Award of Three Collocated Conferences for [C5]**, *IFIP International Conference on Formal Techniques for Distributed Systems: Joint International Conference of 14th Formal Methods for Open Object-Based Distributed Systems and 32nd Formal Techniques for Networked and Distributed Systems (FORTE/FMOODS 2012), of the 7th International Federated Conference on Distributed Computing Techniques (DisCoTec 2012)*, KTH, Stockholm, Sweden.

2012 – 2013 **Computer Engineering Fellowship Sponsored by Intel Corporation**, *Electrical and Computer Engineering, University of Illinois at Urbana-Champaign*, Urbana, IL.

2/2011 **Best Paper Award for [LC1]**, *2nd IEEE Power and Energy Conference at Illinois (PECI)*, Urbana, IL.

12/2009 **Most Interesting Cyber-Physical Systems Research Problem Award for [E1]**, *30th IEEE Real-Time Systems Symposium (RTSS)*, Washington, DC.

2006 **First Place Team, AMD Digital Logic Design Competition**, *Rice University*, Houston, TX.
Teammates: Brent Stephens and Barron Stone

2004 – 2008 **Coca-Cola Scholars Scholarship**.

2004 – 2008 **Robert C. Byrd Honors Scholarship**.

2004 – 2008 **Bluebonnet Electric Cooperative Scholarship of Excellence**.

2004 – 2008 **Glaser Family Charitable Foundation Scholarship**.

2004 – 2008 **USA Funds Access to Education Scholarship**.

2004 **Texas Society of Professional Engineers Scholarship**, *Brazos County Chapter, TX*.

2004 **Second Place in Computer Science**, *Texas State Science and Engineering Fair*, Arlington, TX.

2003 **Finalist in Computer Science**, *Intel International Science and Engineering Fair*, Cleveland, OH.

STUDENT AWARDS AND HONORS

9/2015 **NSF Travel Awards for the PhD Student Forum at Formal Methods in Computer-Aided Design (FMCAD 2015)**, *Luan Viet Nguyen (DS1) and Omar Beg (DA1), Austin, TX, September 27-30, 2015*.

5/2015 **NSF and ACM SIGBED Travel Awards for Cyber-Physical Systems Week (CPSWeek 2015)**, *Luan Viet Nguyen (DS1) and Hoang-Dung Tran (DS3), Seattle, WA, April 12-16, 2015*.

12/2014 **NSF Travel Award for CPS Verification and Validation: Industrial Challenges and Foundations (CPS V&V I&F)**, *Luan Viet Nguyen (DS1), Carnegie Mellon University, Pittsburgh, PA, December 12, 2014*.

12/2014 **3rd Place in US/India Chamber of Commerce Spirit of Innovation Competition**, *Amol Vengurlekar (MA1), Ruoshi Zhang (MA2), Luan Viet Nguyen (DS1), and Eric Nelson (IS2) for project related to paper [W2], which came with a* $1000 *award*.

4/2014 **NSF Graduate Research Fellowship Program (GRFP) Honorable Mention**, *Shamina Shahrin Hossain (MP1), April 2014*.

TEACHING EXPERIENCE

Vanderbilt University

Spring 2018 **Computer Networks (CS4283/CS5283)**, *Instructor*.
35 students

Fall 2017 **Vanderbilt Visions (VUcept) Freshman Seminar (VV0700)**, *Instructor (VUceptor)*.
18 students

Fall 2017 **Discrete Event Systems (CS6375)**, *Instructor*.
9 students

Fall 2017 **Introduction to Engineering, Computer Science Module (ES140x)**, *Instructor*.
75 students total: 25 students each in 3 1-hour modules taught over the semester

Spring 2017 **Automated Verification (CS6315)**, *Instructor*.
9 students

Fall 2016 **Computer Organization (CS2231)**, *Instructor*, This course's student results were used in the 2017 Accreditation Board for Engineering and Technology (ABET) Accreditation for the Computer Science (CS) and Computer Engineering (CmpE) program evaluations..
35 students

University of Connecticut

Spring 2016 **Capstone Projects for Embedded Systems (SE5309), United Technologies Corporation (UTC), Institute for Advanced Systems Engineering (IASE)**, *Adjunct Faculty; Capstone Project Mentor*, Supervised two student teams for capstone embedded system design projects using formal methods concepts and tools as a part of their Embedded Systems Graduate Certificates..
6 students, online-only course

Summer 2015 **Formal Methods (SE5302), United Technologies Corporation (UTC), Institute for Advanced Systems Engineering (IASE)**, *Adjunct Faculty; Instructor of Record (Main Instructor)*, Developed and taught this all online course on formal methods to graduate-level engineers in industry from UTC through the UTC IASE. The online courses were taught to engineers across three continents (in North America, Europe, and Asia). Formal methods tools used include nuXmv, NuSMV, Simulink Design Verifier, Simulink Verification and Validation, Frama-C, Daikon, and PVS. Guest lecturers provided by Prof. Sayan Mitra of Illinois, Dr. Eelco Scholte of UTC, and Jay Abraham of the MathWorks.
26 students, online-only course

University of Texas at Arlington

Fall 2015 **Automated Software Engineering (CSE6323)**, *Instructor*.
9 students; developed course

Summer 2015 **Introduction to Engineering and Engineering Mathematics (ENGR1.0x)**, *Guest Lecturer*, Created modules on computer science mathematics, particularly discrete math and graph theory.
Massive Open Online Course (MOOC) through edX via UTArlingtonX for high school students.

Spring 2015 **Mobile Systems Engineering (CSE4340 / CSE5349)**, *Instructor*.
32 students (18 undergraduates in 4340 and 14 graduates in 5349); redeveloped course

Fall 2014 **Computer Organization and Assembly Language Programming (CSE2312)**, *Instructor*.
49 students; also provided all course materials for another fall 2014 section, which has been reused in five subsequent sections in spring 2015, summer 2015, and fall 2015.

Spring 2014 **Special Topics in Advanced Systems and Architecture: Cyber-Physical Systems (CSE6359)**, *Instructor*.
9 students; developed course

Fall 2013 **Computer Organization and Assembly Language Programming (CSE2312)**, *Instructor*.
47 students; redeveloped course and also provided course materials for spring 2014 and summer 2014 sections.

University of Illinois at Urbana-Champaign

Spring 2010 **Introduction to Computing Systems (ECE190)**, *Graduate Teaching Assistant*.

Spring 2009 **Introduction to Computing Systems (ECE190)**, *Graduate Teaching Assistant*.

Fall 2008 **Introduction to Electrical and Computer Engineering (ECE110)**, *Graduate Teaching Assistant*.

Rice University

Spring 2008 **Applied Algorithms and Data Structures (COMP314)**, *Undergraduate Teaching Assistant*.

Spring 2008 **Intermediate Programming (COMP212)**, *Undergraduate Teaching Assistant*.

Fall 2007 **Digital Logic Design (ELEC326)**, *Undergraduate Lab Assistant*.

Spring 2007 **Intermediate Programming (COMP212)**, *Undergraduate Teaching Assistant*.

Spring 2007 **Microcontroller and Embedded Systems Laboratory (ELEC226)**, *Undergraduate Lab Assistant*.

Spring 2006 **Intermediate Programming (COMP212)**, *Undergraduate Teaching Assistant*.

PUBLICATIONS AND PRESENTATIONS

Citation metrics are from Google Scholar, with a total of 452 citations, h-index of 13, and $i10$-index of 20 as on February 15, 2018.

Co-authors with a trailing † indicate thesis students formally advised or co-advised, with a trailing $^{\circ}$ are postdocs formally mentored, and co-authors with a trailing * indicate students informally mentored. Papers subject to double-blind reviews (both authors and reviewers are anonymous) are indicated by $\odot$. Papers that have corresponding software artifacts and have passed a repeatability evaluation are indicated by ρ.

PAPERS SUBMITTED AND PENDING REVIEW DECISIONS

[U9] Hoang-Dung Tran†, Stanley Bak, ***Taylor T. Johnson***, "Numerical Verification of Affine Systems with up to a Billion Dimensions", under review for 2018 Computer Aided Verification (CAV 2018), January 2018.

[U8] Hoang-Dung Tran†, Weiming Xiang$^{\circ}$, Nathaniel Hamilton†, ***Taylor T. Johnson***, "Reachability Analysis for High-Index Large Linear Differential Algebraic Equations", under review for 2018 Computer Aided Verification (CAV 2018), January 2018.

[U7] Luan Viet Nguyen†, Bardh Hoxha, ***Taylor T. Johnson***, Georgios Fainekos, "Mission Planning for Multiple Vehicles with Temporal Specifications using UxAS," under review for 2018 IFAC Conference on Analysis and Design of Hybrid Systems (ADHS 2018), December 2017.

[U6] Hoang-Dung Tran†, Stanley Bak, ***Taylor T. Johnson***, "Reachability analysis for one-dimensional heat equation,", under review for 2018 IFAC Conference on Analysis and Design of Hybrid Systems (ADHS 2018), December 2017.

[U5] Joel Rosenfeld$^{\circ}$, Patrick Musau†, Ayana Wild†, ***Taylor T. Johnson***, "Tunable Reachable Set Over-approximation for Nonlinear Continuous Systems," under review for 2018 IFAC Conference on Analysis and Design of Hybrid Systems (ADHS 2018), December 2017.

[U4] Omar Beg†, Luan Viet Nguyen†, ***Taylor T. Johnson***, and Ali Davoudi, "Signal Temporal Logic-based Attack Detection in DC Microgrids," under revision for IEEE Transactions on Smart Grid (TSG), December 2017. [pdf]

[U3] Weiming Xiang$^{\circ}$, Hoang-Dung Tran†, ***Taylor T. Johnson***, "Nonconservative Lifted Convex Conditions for Stability of Discrete-Time Switched Systems under Minimum Dwell-Time Constraint", under major revision for IEEE Transactions on Automatic Control (TAC), December 2017.

[U2] Weiming Xiang$^{\circ}$, Diego Manzanas Lopez†, Patrick Musau†, ***Taylor T. Johnson***, "Reachable Set Estimation and Verification for Neural Network Models of Nonlinear Dynamic Systems" under review for "Safe, Autonomous and Intelligent Vehicles," Springer Unmanned System Technologies (UST) Series, Editors: Huafeng Yu, Xin Li, Richard Murray, Claire J. Tomlin, Ramesh S., November 2017. [pdf]

[U1] Weiming Xiang$^{\circ}$, Hoang-Dung Tran†, ***Taylor T. Johnson***, "Reachable Set Computation and Safety Verification for Neural Networks with ReLU Activations", under review for IEEE Transactions on Cybernetics (TCYB), September 2017. [pdf]

REFEREED JOURNAL ARTICLES

[J15] Weiming Xiang$^{\circ}$, Hoang-Dung Tran†, and ***Taylor T. Johnson***, "Robust Exponential Stability and Disturbance Attenuation for Discrete-Time Switched Systems under Arbitrary Switching," IEEE Transactions on Automatic Control (TAC), May 2018 (To Appear). Citations: 1. [pdf]

[J14] Weiming Xiang$^{\circ}$, Hoang-Dung Tran†, ***Taylor T. Johnson***, "Output Reachable Set Estimation and Verification for Multi-Layer Neural Networks", IEEE Transactions on Neural Networks and Learning Systems (TNNLS), February 2018 (To Appear). Citations: 3. [pdf]

[J13] Luan Viet Nguyen†, Khaza Anuaral Hoque$^{\circ}$, ***Taylor T. Johnson***, Stanley Bak, and Steven Drager, "Cyber-Physical Specification Mismatches," ACM Transactions on Cyber-Physical Systems (TCPS), December 2017 (To Appear). [pdf]

[J12] Andrew Sogokon$^{\circ}$, Khalil Ghorbal, and ***Taylor T. Johnson***, "Operational models of piecewise-smooth systems," ACM Transactions on Embedded Computing Systems (TECS), Special Issue ESWEEK 2017, CASES 2017, CODES + ISSS 2017 and EMSOFT 2017, October 2017. [pdf]

[J11] Stanley Bak, Omar Beg†, Sergiy Bogomolov, ***Taylor T. Johnson***, Luan Viet Nguyen†, Christian Schilling, "Embedding Hybrid Automata into Model-Based Design," Springer Software Tools for Technology Transfer (STTT), May 2017. [pdf] Software tool: `http://swt.informatik.uni-freiburg.de/tool/spaceex/ha2slsf`

[J10] Omar Beg†, Houssam Abbas, ***Taylor T. Johnson***, and Ali Davoudi, "Model Validation of PWM DC-DC Converters," IEEE Transactions on Industrial Electronics (TIE), March 2017. Citations: 2. [pdf]

[J9] Weiming Xiang°, Hoang-Dung Tran†, and ***Taylor T. Johnson***, "Output Reachable Set Estimation for Switched Linear Systems and Its Application in Safety Verification," IEEE Transactions on Automatic Control, March 2017. Citations: 1. [pdf]

[J8] Weiming Xiang° and ***Taylor T. Johnson***, "Event-Triggered Control for Continuous-Time Switched Linear Systems," IET Control Theory and Applications, February 2017. [pdf]

[J7] Hoang-Dung Tran†, Luan Viet Nguyen†, Weiming Xiang°, and ***Taylor T. Johnson***, "An Automatic Order-Reduction Abstraction for Safety Verification of Periodically Switched Systems," Springer Discrete Event Dynamic Systems, Special Issue on Formal Methods in Control, February 2017. Citations: 8. [pdf]

[J6] Omar Beg†, ***Taylor T. Johnson***, and Ali Davoudi, "Detection of False-data Injection Attacks in Cyber-Physical DC Microgrids," IEEE Transactions on Industrial Informatics (TII), Special Section on Systems of Power Converters: Design, Modeling, Control, and Implementation, January 2017. Citations: 4. [pdf]

[J5] Sergiy Bogomolov, Alexandre Donzé, Goran Frehse, Radu Grosu, ***Taylor T. Johnson***, Hamed Ladan, Andreas Podelski, and Martin Wehrle. "Abstraction-Based Guided Search for Hybrid Systems," August 2016, *International Journal on Software Tools for Technology Transfer (STTT)*, Springer. Extension of [C8] (Special Issue from SPIN 2013). Citations: 20. [pdf] Software tool: `http://www2.informatik.uni-freiburg.de/~bogom/sttt2015/`

[J4] ***Taylor T. Johnson***, Stanley Bak, Marco Caccamo, and Lui Sha, "Real-Time Reachability for Verified Simplex Design," *ACM Transactions on Embedded Computing Systems (TECS)*, February 2016. Extension of [C11]. Software Tool: `https://bitbucket.org/verivital/rtreach` Citations: 7. [pdf]

[J3] ***Taylor T. Johnson*** and Sayan Mitra. "Safe and Stabilizing Distributed Multi-Path Cellular Flows," *Theoretical Computer Science (TCS)*, Elsevier, Volume 579, May 2015. Extension of [C1]. Software Tool: `https://bitbucket.org/verivital/cell_flows` Citations: 4. [pdf]

[J2] Luan Viet Nguyen†, Hoang-Dung Tran† and ***Taylor T. Johnson***. "Virtual Prototyping for Distributed Control of a Fault-Tolerant Modular Multilevel Inverter for Photovoltaics," *IEEE Transactions on Energy Conversion (TEC)*, Special Issue on Advanced Distributed Control of Energy Conversion Devices and Systems, December 2014. Citations: 21. [pdf]

[J1] ***Taylor T. Johnson*** and Sayan Mitra. "Safe Flocking in Spite of Actuator Faults Using Directional Failure Detectors," in *Journal of Nonlinear Systems and Applications (JNSA)*, Watam Press, Waterloo, Canada, 2011. Extension of [C2]. Citations: 16. [pdf]

REFEREED CONFERENCE PROCEEDINGS PAPERS

Acceptance based on peer review of full papers..

[C30] Weiming Xiang°, Hoang-Dung Tran†, Joel Rosenfeld°, ***Taylor T. Johnson***, "Reachable Set Estimation and Verification for a Class of Piecewise Linear Systems with Neural Network Controllers," under review for Invited Session on "Formal Methods in Controller Synthesis I," 2018 American Control Conference (ACC 2018), Organizers: Agung Julius, Jun Liu, Necmiye Ozay, June 2018 (To Appear). [pdf]

[C29] Shafiul Chowdhury†, Soumik Mohian, Sidharth Mehra, Siddhant Gawsane, ***Taylor T. Johnson***, Christoph Csallner, "Automatically Finding Bugs in a Commercial Cyber-Physical System Development Tool Chain With SLforge," 40th ACM International Conference on Software Engineering (ICSE 2018), Gothenburg, Sweden, May 27 to June 3, 2018 (To Appear as a Full Technical Paper). Related software tools SLForge and CyFuzz [S5]. $\odot$ ρ Acceptance Rate: 20.9% (105 of 502). [pdf]

[C28] Luan Viet Nguyen†, James Kapinski, Xiaoqing Jin, Jyotirmoy Deshmukh, and ***Taylor T. Johnson***, "Hyperproperties of Real-Valued Signals," 15th ACM-IEEE International Conference on Formal Methods and Models for System Design (MEMOCODE 2017), Vienna, Austria, September 2017. Citations: 1. [pdf]

[C27] Andrew Sogokon°, Khalil Ghorbal, and ***Taylor T. Johnson***, "Operational models of piecewise-smooth systems," 15th International Conference on Embedded Software 2017 (EMSOFT 2017), ESWeek 2017, Seoul, South Korea, October 2017. [pdf]

[C26] Omar Beg†, Luan Viet Nguyen†, Ali Davoudi, and ***Taylor T. Johnson***, "Computer-Aided Formal Verification of Power Electronics Circuits," IEEE Frontiers in Analog CAD (FAC), July 2017. [pdf]

[C25] Weiming Xiang°, ***Taylor T. Johnson***, and Hoang-Dung Tran†, "On Reachable Set Estimation for Discrete-Time Switched Linear Systems under Arbitrary Switching," IEEE American Control Conference (ACC 2017), May 2017. [pdf]

[C24] Andrew Sogokon°, Paul Jackson, and ***Taylor T. Johnson***, " Verifying safety and persistence properties of hybrid systems using flowpipes and continuous invariants," 9th NASA Formal Methods Symposium (NFM 2017), Moffett Field, CA, May 2017. Acceptance Rate: 38.3% (23 of 60). [pdf]

[C23] Luan Viet Nguyen†, James Kapinski, Xiaoqing Jin, Jyotirmoy Deshmukh, Ken Butts, ***Taylor T. Johnson***, "Abnormal Data Classification Using Time-Frequency Temporal Logic," Hybrid Systems Computation and Control 2017 (HSCC 2017), CPSWeek 2017, Pittsburgh, PA, April 2017. $\odot$ ρ Acceptance Rate: 38.2% (29 of 76). Citations: 4. [pdf]

[C22] Umair Siddique, Khaza Anuaral Hoque°, ***Taylor T. Johnson***, "Formal Specification and Dependability Analysis of Optical Communication Networks," 20th International Conference on Design, Automation, and Test in Europe (DATE 2017), Lausanne, Switzerland, March 2017. Acceptance Rate: 24.3% (193 of 794). [pdf]

[C21] Weiming Xiang°, Hoang-Dung Tran†, and ***Taylor T. Johnson***, "Reachable Set Estimation and Control for Switched Linear Systems with Dwell-Time Restriction," IEEE Conference on Decision and Control [CDC 2016], December 2016. Acceptance Rate: 59.5% (1242 of 2086). [pdf]

[C20] Andrew Sogokon°, Khalil Ghorbal, ***Taylor T. Johnson***, "Decoupled simulating abstractions of non-linear ordinary differential equations", Chapter in Proceedings of the 21st International Symposium on Formal Methods (FM 2016), Limassol, Cyprus, November 2016. Acceptance Rate: 28.5% (43 of 151). [pdf]

[C19] Parasara Sridhar Duggirala, Chuchu Fan, Matthew Potok, Bolun Qi, Sayan Mitra, Mahesh Viswanathan, Stanley Bak, Sergiy Bogomolov, ***Taylor T. Johnson***, Luan Viet Nguyen†, Christian Schilling, Andrew Sogokon°, Hoang-Dung Tran†, Weiming Xiang°. "Tutorial: Software Tools for Hybrid Systems Verification, Transformation, and Synthesis: C2E2, HyST, and TuLiP," IEEE Multi-Conference on Systems and Control (MSC 2016), Buenos Aires, Argentina, September 2016. Citations: 2. [pdf]

[C18] Muhammad Usama Sardar, Nida Afaq, Khaza Anuaral Hoque°, ***Taylor T. Johnson***, Osman Hasan, "Probabilistic Formal Verification of the SATS Concept of Operation", In Proceedings of the 8th NASA Formal Methods (NFM 2016) International Symposium (Sanjai Rayadurgam, Oksana Tkachuk, eds.), Springer International Publishing, pp. 191-205, June 2016. Acceptance Rate: 37.3% (19 of 51). Citations: 3. [pdf]

[C17] Stanley Bak, Sergiy Bogomolov, Thomas A. Henzinger, ***Taylor T. Johnson***, and Pradyot Prakash, "Scalable Static Hybridization Methods for Analysis of Nonlinear Systems," Hybrid Systems Computation and Control 2016 (HSCC 2016), CPSWeek 2016, Vienna, Austria, April 2016. **Best Software Repeatability Evaluation Award**. Acceptance Rate: 43.1% (28 of 65). Citations: 11. [pdf]

[C16] Stanley Bak and ***Taylor T. Johnson***, "Periodically-Scheduled Controller Analysis using Hybrid Systems Reachability and Continuization," *36th IEEE Real-Time Systems Symposium (RTSS)*, Cyber-Physical Systems (CPS) Track, San Antonio, Texas, December 2015. Acceptance Rate: 22.5% (34 of 151). Citations: 8. [pdf]

[C15] Luan Viet Nguyen†, Christian Schilling, Sergiy Bogomolov, and ***Taylor T. Johnson***, "Runtime Verification for Hybrid Analysis Tools," *15th International Conference on Runtime Verification (RV 2015)*, Vienna, Austria, September 2015. [pdf]

[C14] ***Taylor T. Johnson***, Stanley Bak, and Steven Drager, "Cyber-Physical Specification Mismatch Identification with Dynamic Analysis," *6th ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS 2015)*, CPSWeek 2015, Seattle, Washington, April 2015. Software Tool: `http://verivital.com/hynger/` Acceptance Rate: 27.5% (25 of 91). Citations: 11. [pdf]

[C13] Stanley Bak, Sergiy Bogomolov, and ***Taylor T. Johnson***, "HyST: A Source Transformation and Translation Tool for Hybrid Automaton Models," *18th International Conference on Hybrid Systems: Computation and Control (HSCC 2015)*, CPSWeek 2015, Seattle, Washington, April 2015. Software Tool: `http://verivital.com/hyst/` ρ Acceptance Rate: 39.5% (30 of 76). Citations: 45. [pdf]

[C12] Leonardo Bobadilla, ***Taylor T. Johnson***, Amy LaViers, and Umer Huzaifa. "Verified Planar Formation Control Algorithms by Composition of Primitives," *AIAA SciTech*, Kissimmee, FL, January 2015. [pdf]

[C11] Stanley Bak, ***Taylor T. Johnson***, Marco Caccamo, and Lui Sha. "Real-Time Reachability for Verified Simplex Design," *35th IEEE Real-Time Systems Symposium (RTSS)*, Rome, Italy, December 2014. Software Tool: `https://bitbucket.org/verivital/rtreach` Acceptance Rate: 21.4% (33 of 154). Citations: 24. [pdf]

[C10] ***Taylor T. Johnson*** and Sayan Mitra. "Anonymized Reachability of Hybrid Automata Networks," *12th International Conference on Formal Modeling and Analysis of Timed Systems (FORMATS)*, Florence, Italy, September 2014. Acceptance Rate: 47.2% (17 of 36). Citations: 3. [pdf]

[C9] ***Taylor T. Johnson*** and Sayan Mitra. "Invariant Synthesis for Verification of Parameterized Cyber-Physical Systems with Applications to Aerospace Systems," *AIAA Infotech*, Boston, Massachusetts, August 2013. [pdf]

[C8] Sergiy Bogomolov, Alexandre Donzé, Goran Frehse, Radu Grosu, ***Taylor T. Johnson***, Hamed Ladan, Andreas Podelski, and Martin Wehrle. "Abstraction-Based Guided Search for Hybrid Systems," *20th International SPIN Symposium on Model Checking of Software (SPIN)*, Stony Brook, New York, July 2013. Acceptance Rate: 50.0% (20 of 40). Citations: 17. [pdf]

[C7] Parasara Sridhar Duggirala, ***Taylor T. Johnson***, Adam Zimmerman, and Sayan Mitra. "Static and Dynamic Analysis of Timed Distributed Traces," in *33rd IEEE Real-Time Systems Symposium (RTSS)*, San Juan, Puerto Rico, December 2012. Acceptance Rate: 22.3% (35 of 157). Citations: 18. [pdf]

[C6] ***Taylor T. Johnson***, Jeremy Green, Sayan Mitra, Rachel Dudley, and R. Scott Erwin. "Verifying Satellite Rendezvous and Conjunction Avoidance: Case studies in verification of nonlinear hybrid systems," in *18th International Symposium on Formal Methods (FM)*, Paris, France, August 2012. Acceptance Rate: 21.2% (28 of 132). Citations: 21. [pdf]

[C5] ***Taylor T. Johnson*** and Sayan Mitra. "A Small Model Theorem for Rectangular Hybrid Automata Networks," in *IFIP International Conference on Formal Techniques for Distributed Systems: Joint International Conference of 14th Formal Methods for Open Object-Based Distributed Systems and 32nd Formal Techniques for Networked and Distributed Systems (FORTE/FMOODS)*, Stockholm, Sweden, June 2012. **Best Paper Award**. Top 1 of 155 Submissions Across Three Conferences. Acceptance Rate: 38.1% (16 of 42). Citations: 30. [pdf]

[C4] ***Taylor T. Johnson*** and Sayan Mitra. "Parameterized Verification of Distributed Cyber-Physical Systems: An Aircraft Landing Protocol Case Study," in *3rd ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS)*, Beijing, China, April 2012. Acceptance Rate: 34.1% (14 of 41). Citations: 29. [pdf]

[C3] ***Taylor T. Johnson***, Sayan Mitra, and Cédric Langbort. "Stability of Digitally Interconnected Linear Systems," in *50th IEEE Conference on Decision and Control and European Control Conference (CDC/ECC)*, Orlando, Florida, December 2011. Citations: 5. [pdf]

[C2] ***Taylor T. Johnson*** and Sayan Mitra. "Safe Flocking in Spite of Actuator Faults," in *12th International Symposium on Stabilization, Safety, and Security of Distributed Systems (SSS)*, New York, New York, September 2010. Acceptance Rate: 43.3% (39 of 90). Citations: 7. [pdf]

[C1] ***Taylor T. Johnson***, Sayan Mitra, and Karthik Manamcheri. "Safe and Stabilizing Distributed Cellular Flows," in *30th IEEE International Conference on Distributed Computing Systems (ICDCS)*, Genoa, Italy, June 2010. Acceptance Rate: 14.4% (84 of 585). Citations: 14. [pdf]

LIGHTLY REFEREED CONFERENCE PROCEEDINGS PAPERS

Acceptance based on peer review of abstracts or short papers..

[LC4] ***Taylor T. Johnson***, Raghunath Gannamaraju, and Sebastian Fischmeister, "A Survey of Electrical and Electronic (E/E) Notifications for Motor Vehicles," *24th NHTSA International Technical Conference on the Enhanced Safety of Vehicles (ESV 2015)*, Paper Number 15-0063, Gothenburg, Sweden, June 2015. Citations: 4. [pdf]

[LC3] Shamina Shahrin Hossain*, Sairaj Dhople, and ***Taylor T. Johnson***. "Reachability Analysis of Closed-Loop Switching Power Converters," in *4th IEEE Power and Energy Conference at Illinois (PECI)*, Urbana, Illinois, February 2013. Citations: 10. [pdf]

[LC2] ***Taylor T. Johnson***, Zhihao Hong*, and Akash Kapoor*. "Design Verification Methods for Switching Power Converters," in *3rd IEEE Power and Energy Conference at Illinois (PECI)*, Urbana, Illinois, February 2012. Citations: 14. [pdf]

[LC1] ***Taylor T. Johnson*** and Albert E. Hoefel. "Turbo-Alternator Stalling Protection using Available Power Estimate," in *2nd IEEE Power and Energy Conference at Illinois (PECI)*, Urbana, Illinois, February 2011. **Best Paper Award**. Citations: 2. [pdf]

REFEREED WORKSHOP PROCEEDINGS PAPERS

Acceptance based on peer review of full papers..

[W14] ***Taylor T. Johnson***, "Reusable and Understandable Formal Verification for Cyber-Physical Systems," 1st International Workshop on Formal Approaches to Explainable VERification (FEVER 2017), Co-located with CAV 2017, Heidelberg, Germany, July 2017. [pdf]

[W13] ***Taylor T. Johnson***, "ARCH-COMP17 Repeatability Evaluation Report," 4th International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2017), Co-located with CPSWeek 2017, Pittsburgh, PA, April 2017. [pdf]

[W12] Hoang-Dung Tran†, Luan Viet Nguyen†, Weiming Xiang°, and ***Taylor T. Johnson***, "Distributed Autonomous Systems (Benchmark Proposal)," 4th International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2017), Co-located with CPSWeek 2017, Pittsburgh, PA, April 2017. [pdf]

[W11] Omar Beg†, Ali Davoudi, and ***Taylor T. Johnson***, "Reachability Analysis of Transformer-Isolated DC-DC Converters (Benchmark Proposal)," 4th International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2017), Co-located with CPSWeek 2017, Pittsburgh, PA, April 2017. [pdf]

[W10] Shafiul Chowdhury†, ***Taylor T. Johnson***, and Christoph Csallner "CyFuzz: A Differential Testing Framework for Cyber-Physical Systems Development Environments," 6th International Workshop on Design, Modeling and Evaluation of Cyber Physical Systems (CyPhy 2016), Co-located with Embedded Systems Week (ESweek) 2016, Pittsburgh, PA, August 2016. Acceptance Rate: 60.0% (9 of 15). Citations: 1. [pdf]

[W9] Hoang-Dung Tran†, Luan Viet Nguyen†, and ***Taylor T. Johnson***, "Large-Scale Linear Systems from Order-Reduction (Benchmark Proposal)," 3rd International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2016), Co-located with CPSWeek 2016, Vienna, Austria, April 2016. Citations: 3. [pdf]

[W8] Andrew Sogokon°, Khalil Ghorbal, and ***Taylor T. Johnson***, "Non-linear Continuous Systems for Safety Verification (Benchmark Proposal)," 3rd International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2016), Co-located with CPSWeek 2016, Vienna, Austria, April 2016. Citations: 1. [pdf]

[W7] Omar Beg†, Ali Davoudi, and ***Taylor T. Johnson***, "Charge Pump Phase-Locked Loops and Full Wave Rectifiers for Reachability Analysis (Benchmark Proposal)," 3rd International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2016), Co-located with CPSWeek 2016, Vienna, Austria, April 2016. Citations: 1. [pdf]

[W6] Luan Viet Nguyen†, Djordje Maksimovic, ***Taylor T. Johnson***, and Andreas Veneris, "Quantified Bounded Model Checking for Rectangular Hybrid Automata," 9th International Workshop on Constraints in Formal Verification (CFV 2015), Co-located with the 34th IEEE/ACM International Conference On Computer Aided Design (ICCAD 2015), November 2015. [pdf]

[W5] Stanley Bak, Sergiy Bogomolov, and ***Taylor T. Johnson***, "HYST: A Source Transformation and Translation Tool for Hybrid Automaton Models," 1st International Workshop on Symbolic and Numerical Methods for Reachability Analysis (SNR 2015), Co-located with the 27th International Conference on Computer Aided Verification (CAV 2015), San Francisco, California, July 19, 2015. [pdf]

[W4] Hoang-Dung Tran†, Luan Viet Nguyen†, and ***Taylor T. Johnson***, "Benchmark: A Nonlinear Reachability Analysis Test Set from Numerical Analysis," 2nd International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2015), Co-located with CPSWeek 2015, Seattle, Washington, April 2015. Citations: 3. [pdf]

[W3] Stanley Bak, Sergiy Bogomolov, Marius Greitschus, and ***Taylor T. Johnson***, "Benchmark Generator for Stratified Controllers of Tank Networks," 2nd International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2015), Co-located with CPSWeek 2015, Seattle, Washington, April 2015. Citations: 1. [pdf]

[W2] Luan Viet Nguyen†, Eric Nelson⋆, Amol Vengurlekar†, Ruoshi Zhang†, Kristopher I. White, Victor Salinas, and ***Taylor T. Johnson***. "Model-Based Design and Analysis of a Reconfigurable Continuous-Culture Bioreactor," in *4th ACM SIGBED International Workshop on Design, Modeling, and Evaluation of Cyber-Physical Systems (CyPhy)*, Co-located with CPSWeek 2014, Berlin, Germany, April 2014. Acceptance Rate: 50.0% (14 of 28). Citations: 1. [pdf]

[W1] Luan Viet Nguyen†, and ***Taylor T. Johnson***. "Benchmark: DC-to-DC Switched-Mode Power Converters (Buck Converters, Boost Converters, and Buck-Boost Converters)," in *Applied Verification for Continuous and Hybrid Systems Workshop (ARCH)*, Co-located with CPSWeek 2014, Berlin, Germany, April 2014. Citations: 15. [pdf]

POSITION/EDITORIAL/OPINION PAPERS

Acceptance based on peer review of abstracts or short papers..

[E1] ***Taylor T. Johnson*** and Sayan Mitra, "Handling Failures in Cyber-Physical Systems: Potential Directions," PhD Student Forum on Cyber-Physical Systems, 30th IEEE Real-Time Systems Symposium (RTSS), Washington, DC, December 1, 2009. (**Award for *Most Interesting Cyber-Physical Systems Research Problem***). Citations: 5. [pdf]

PATENTS AND PATENT APPLICATIONS

[P2] "Systems and Methods for Providing Speech-to-Text Recognition and Autosummarization," ***Taylor T. Johnson***. VU 17131, MCC Docket Number 10644-043PV1, Patent Application, February 1, 2018.

[P1] "Control of a Component of a Downhole Tool", Albert Hoefel, Francois Bernard, Kent D. Harms, Sylvain Ramshaw, Shayan Darayan, and ***Taylor T. Johnson***. Patent No. US 9222352, Patent Issued December 29, 2015. Based in part on paper [LC1]. [pdf]

PRESENTATIONS

KEYNOTE/PLENARY PRESENTATIONS

[KT1] Keynote presentation, based on paper [C11], "Real-Time Reachability for Verified Simplex Design," at *8th International Workshop on Numerical Software Verification 2015* (NSV 2015) at Cyber-Physical Systems Week (CPS Week 2015), Seattle, WA, April 13, 2015.

INVITED PRESENTATIONS

[IT28] Presented "Software Defects in Medical Devices," in conjunction with Prof. Pampee Young's presentation "Software Error in Blood Bank Systems," Vanderbilt University Medical Center (VUMC), Department of Medicine, Division of Hematology and Oncology, Laboratory Medicine Rounds, November 10, 2017.

[IT27] Presented "Real-Time Reachability for Safety Verification of Autonomous Cyber-Physical Systems," at the CPS Verification & Validation: Industrial Challenges & Foundations: Safe Implementation of CPS, Carnegie Mellon University, Pittsburgh, PA, May 12, 2017.

[IT26] Presented "Real-Time Reachability for Safety of Autonomous Systems," at the Computer Science and Engineering Graduate Seminar (CSCE 681), Texas A&M University, College Station, TX, March 6, 2017.

[IT25] Presented "Real-Time Reachability for Verification of Autonomous Cyber-Physical Systems," at the Electrical and Computer Engineering Seminar Series (ECE698/699), Rice University, Houston, TX, March 3, 2017.

[IT24] Presented "Real-Time Reachability for Verification of Autonomous Systems," at the Computer Science Seminar, University of Houston, Houston, TX, February 20, 2017.

[IT23] Invited Presentation, "Cyber-Physical Specification Mismatches," at the Air Force Research Laboratory, Air Vehicles Directorate, Wright-Patterson Air Force Base, Dayton, OH, June 28, 2016.

[IT22] Invited Presentation, "Hybrid automata: from verification to implementation," at the Mathworks Faculty Research Summit, Natick, MA, June 4, 2016.

[IT21] Invited Presentation, "Automated Formal Verification for Cyber-Physical Systems," at the Federal Laboratory Day, Laboratory for Telecommunication Sciences, University of Maryland, College Park, MD, March 29, 2016.

[IT20] Invited Presentation, "Automated Formal Verification for Cyber-Physical Systems," at the Electrical Engineering and Computer Science Department, Vanderbilt University, Nashville, TN, March 14, 2016.

[IT19] Invited Presentation, "Automated Formal Verification for Aerospace Cyber-Physical Systems," at the Aerospace Engineering Department Seminar, University of Michigan, Ann Arbor, MI, March 8, 2016.

[IT18] Presented "Temporal and Functional Correctness in Support of Systems Biology Research," at the Green Center for Systems Biology, University of Texas Southwestern Medical Center at Dallas (UT Southwestern), Dallas, TX, January 13, 2016.

[IT17] Presented "Automating Verification of Cyber-Physical Systems with HyST," at the Formal Methods Seminar, Department of Computer Science, University of Illinois at Urbana-Champaign, Urbana, IL, December 11, 2015.

[IT16] Presented "Real-Time Reachability of Hybrid Systems for Formally Verified Supervisory Control," at the Electrical Engineering Colloquium, University of North Texas, Denton, TX, September 18, 2015.

[IT15] Invited presentation, "Automated Formal Verification of Distributed Cyber-Physical Systems," at Systems and Information Engineering Department Colloquium, University of Virginia, Charlottesville, VA, December 19, 2014.

[IT14] Invited presentation, "Cyber-Physical Specification Mismatch Identification with Dynamic Analysis," at the CPS Verification and Validation: Industrial Challenges and Foundations (CPS V&V I&F), Carnegie Mellon University, Pittsburgh, PA, December 12, 2014.

[IT13] Invited presentation, "Software Verification and Validation Methods: Automated Formal Verification of Distributed Cyber-Physical Systems," at the IEEE Metrocon, Arlington, TX, October 2, 2014.

[IT12] Presented, "Automated Formal Verification of Distributed Cyber-Physical Systems," at School of Computer Science Colloquium, McGill University, Montreal, Quebec, Canada, August 12, 2014.

[IT11] Presented, "Automated Formal Verification of Distributed Cyber-Physical Systems," at Electrical and Computer Engineering Colloquium, University of Waterloo, Waterloo, Ontario, Canada, July 25, 2014.

[IT10] Presented, "Automated Formal Verification of Distributed Cyber-Physical Systems," at the Air Force Research Laboratory's Safe & Secure Systems and Software Symposium (S5), Dayton, OH, June 10, 2014.

[IT9] Invited presentation, "Automated Formal Verification of Distributed Cyber-Physical Systems," at the Trust and Security Seminar, Information Trust Institute, University of Illinois at Urbana-Champaign, Urbana, IL, May 16, 2014.

[IT8] Presented "Automated Formal Verification for Reliable Cyber-Physical Systems," Computer Science and Engineering Colloquium, Southern Methodist University, Dallas, TX, April 2, 2014.

[IT7] Invited presentation, "Verification Techniques and Tools for Reliable Cyber-Physical Systems," University of Pennsylvania, Philadelphia, TX, April 3, 2013.

[IT6] Invited presentation, "Verification Techniques and Tools for Reliable Cyber-Physical Systems," Sandia National Laboratory, Livermore, CA, March 20, 2013.

[IT5] Invited presentation, "Verification Techniques and Tools for Reliable Cyber-Physical Systems," University of Texas at San Antonio, San Antonio, TX, March 17, 2013.

[IT4] Invited presentation, "Verification Techniques and Tools for Reliable Cyber-Physical Systems," Texas State University, San Marcos, TX, March 5, 2013.

[IT3] Invited presentation, "Verification Techniques and Tools for Reliable Cyber-Physical Systems," University of Texas at Arlington, Arlington, TX, March 4, 2013.

[IT2] Invited presentation, "Verification Techniques and Tools for Reliable Cyber-Physical Systems," Old Dominion University, Norfolk, VA, March 1, 2013.

[IT1] Invited presentation, "Safety Verification for Parameterized Hybrid Automata Networks," at Formal Methods in Systems Engineering (FORSYTE), Austrian Society for Rigorous Systems Engineering (ARiSE), Technische Universität Wien and Institute of Science and Technology Austria, Vienna, Austria, January 24, 2013.

CONFERENCE PAPER PRESENTATIONS

[CT14] Presented paper [C18], "Probabilistic Formal Verification of the SATS Concept of Operation," at the 8th NASA International Symposium on Formal Methods (NFM 2016), Minneapolis, MN, June 8, 2016.

[CT13] Presented paper [W7], "Charge Pump Phase-Locked Loops and Full Wave Rectifiers for Reachability Analysis (Benchmark Proposal),"at Applied Verification for Continuous and Hybrid Systems (ARCH), Workshop Co-located with CPSWeek 2016, Vienna, Austria, April 11, 2016.

[CT12] Presented paper [W9], "Large-Scale Linear Systems from Order-Reduction (Benchmark Proposal),"at Applied Verification for Continuous and Hybrid Systems (ARCH), Workshop Co-located with CPSWeek 2016, Vienna, Austria, April 11, 2016.

[CT11] Presented paper [W6], "Quantified Bounded Model Checking for Rectangular Hybrid Automata," at the 9th International Workshop on Constraints in Formal Verification (CFV 2015), Austin, TX, November 5, 2015.

[CT10] Presented paper [LC4], "A Survey of Electrical and Electronic (E/E) Notifications for Motor Vehicles," 24th NHTSA International Technical Conference on the Enhanced Safety of Vehicles (ESV 2015), Paper Number 15-0063, Gothenburg, Sweden, June 9, 2015.

[CT9] Presented paper [C14], "Cyber-Physical Specification Mismatch Identification with Dynamic Analysis," at *International Conference on Cyber-Physical Systems* (ICCPS 2015) at Cyber-Physical Systems Week (CPS Week 2015), Seattle, WA, April 16, 2015.

[CT8] Presented paper [C12], "Verified Planar Formation Control Algorithms by Composition of Primitives," at *AIAA SciTech*, Kissimmee, FL, January 8, 2015.

[CT7] Presented paper [C10], "Anonymized Reachability of Hybrid Automata Networks," at *12th International Conference on Formal Modeling and Analysis of Timed Systems (FORMATS)*, Florence, Italy, September 9, 2014.

[CT6] Presented paper [W2], "Model-Based Design and Analysis of a Reconfigurable Continuous-Culture Bioreactor," at 4th ACM SIGBED International Workshop on Design, Modeling, and Evaluation of Cyber-Physical Systems, Workshop Co-located with CPSWeek 2014, Berlin, Germany, April 14, 2014.

[CT5] Presented paper [W1], "Benchmark: DC-to-DC Switched-Mode Power Converters (Buck Converters, Boost Converters, and Buck-Boost Converters)," at Applied Verification for Continuous and Hybrid Systems (ARCH), Workshop Co-located with CPSWeek 2014, Berlin, Germany, April 14, 2014.

[CT4] Presented paper [C5], "A Small Model Theorem for Rectangular Hybrid Automata Networks," at the *IFIP International Conference on Formal Techniques for Distributed Systems: Joint International Conference of 14th Formal Methods for Open Object-Based Distributed Systems and 32nd Formal Techniques for Networked and Distributed Systems (FORTE/FMOODS)*, KTH, Stockholm, Sweden, June 15, 2012. (**Best Paper Award**).

[CT3] Presented paper [LC2], "Design Verification Methods for Switching Power Converters," at the *3rd IEEE Power and Energy Conference at Illinois (PECI)*, University of Illinois at Urbana-Champaign, Champaign, IL, February 24, 2012.

[CT2] Presented paper [LC1], "Turbo-Alternator Stalling Protection using Available Power Estimate," at the *2nd IEEE Power and Energy Conference at Illinois (PECI)*, University of Illinois at Urbana-Champaign, Urbana, IL, February 25, 2011. (**Best Paper Award**).

[CT1] Presented paper [C2], "Safe Flocking in Spite of Actuator Faults," at *12th International Symposium on Stabilization, Safety, and Security of Distributed Systems (SSS)*, New York, NY, September 22, 2010.

OTHER PRESENTATIONS

[OT12] Presented "Automated Formal Verification for Cyber-Physical Systems," at the College of Engineering Advisory Board Meeting, University of Texas at Arlington, Arlington, TX, January 29, 2016.

[OT11] Omar Beg† presented, "Formal Verification for Software-Controlled Power Electronics," at the Air Force Research Laboratory's Safe & Secure Systems and Software Symposium (S5), Dayton, OH, June 11, 2015.

[OT10] Presented, "Automated Formal Verification of Distributed Cyber-Physical Systems," at the Air Force Research Laboratory's Information Directorate, Rome, NY, August 5, 2014.

[OT9] Presented, "Safe Flocking in Spite of Actuator Faults and Planar Distributed Formation Control with One-Dimensional Primitives," at the Air Force Research Laboratory's Information Directorate, Rome, NY, July 23, 2014.

[OT8] Presented "Automatic Safety Verification of Distributed Cyber-Physical Systems," Texas Systems Day, Texas A&M University, College Station, TX, March 28, 2014.

[OT7] Presented "Verification and Validation for Reliable Cyber-Physical Systems," at the Computer Science Colloquium, University of Texas at Arlington, Arlington, TX, November 11, 2013.

[OT6] Presented "Safety Verification of Distributed Cyber-Physical Systems," at the Formal Methods Seminar, Department of Computer Science, University of Illinois at Urbana-Champaign, Urbana, IL, September 27, 2012.

[OT5] Presented paper [C3], "Stability of Digitally Interconnected Linear Systems" at the 7th CSL Student Conference, January 27, 2012, Urbana, IL.

[OT4] Presented "Fault-Tolerant Distributed Cyber-Physical Systems" to the Control Systems Group, University of New Mexico, Albuquerque, NM, June 16, 2011.

[OT3] Presented "Automatic Parameterized Verification of Distributed Algorithms" at 6th CSL Student Conference, Urbana, IL, January 28, 2011.

[OT2] Presented paper [C1], "Safe and Stabilizing Distributed Cellular Flows" to the Multi-Robot Systems Lab, Rice University, Houston, TX, July 15, 2010.

[OT1] Presented paper [C1], "Safe and Stabilizing Distributed Cellular Flows" at the 5th CSL Student Conference, Urbana, IL, January 29, 2010.

DEMONSTRATION PRESENTATIONS

Acceptance based on peer review of abstracts or short papers..

[D4] Shafiul Chowdhury†, ***Taylor T. Johnson***, and Christoph Csallner, "Fuzzing Cyber-Physical System Development Environments With CyFuzz," Demo Session, 20th International Conference on Hybrid Systems: Computation and Control (HSCC 2017), CPSWeek 2017, Pittsburgh, PA, April 2017.

[D3] Presented demo, "Hybrid Systems Model Transformations with HyST," at the 8th NASA International Symposium on Formal Methods (NFM 2016), Minneapolis, MN, June 7, 2016.

[D2] Stanley Bak, Sergiy Bogomolov, and ***Taylor T. Johnson***, "HyST: A Source Transformation and Translation Tool for Hybrid Automaton Models," Demonstration Session, 18th International Conference on Hybrid Systems: Computation and Control (HSCC 2015), CPSWeek 2015, Seattle, Washington, April 2015.

[D1] ***Taylor T. Johnson*** and Sayan Mitra, "The Passel Verification Tool for Hybrid Automata Networks," Demonstration Session, 16th ACM International Conference on Hybrid Systems: Computation and Control (HSCC), CPSWeek 2013, Philadelphia, PA, April 9, 2013.

POSTER PRESENTATIONS

Acceptance based on peer review of abstracts, short papers, or posters..

[Po12] Nathaniel Hamilton† and ***Taylor T. Johnson***, "Architecture for an Indoor Distributed Cyber-Physical System Composed of Mobile Robots and Fog Computing Nodes," Poster Session, Safe and Secure Systems and Software Symposium (S5 2017), Dayton, Ohio, August 2017.

[Po11] Christina Wang† and ***Taylor T. Johnson***, "Moving Target Tracking with Formation Control by Groups of UAVs," Poster Session, Safe and Secure Systems and Software Symposium (S5 2017), Dayton, Ohio, August 2017.

[Po10] Luan Viet Nguyen†, James Kapinski, Xiaoqing Jin, Jyotirmoy V. Deskmukh, and ***Taylor T. Johnson***, "Hyperproperties of Real-Valued Signals," Poster Session, 20th International Conference on Hybrid Systems: Computation and Control (HSCC 2017), CPSWeek 2017, Pittsburgh, PA, April 2017.

[Po9] Luan Viet Nguyen† and ***Taylor T. Johnson***, "Towards Bounded Model Checking for Timed and Hybrid Automata with a Quantified Encoding," PhD Student Forum, Oral and Poster Sessions, 15th International Conference on Formal Methods in Computer-Aided Design (FMCAD), Austin, TX, September 27-30, 2015.

[Po8] Omar Beg† and ***Taylor T. Johnson***, "Computer-Aided Formal Verification for Power Electronics Cyber-Physical systems," PhD Student Forum, Poster Session, 15th International Conference on Formal Methods in Computer-Aided Design (FMCAD), Austin, TX, September 27-30, 2015.

[Po7] Luan Viet Nguyen†, Christian Schilling, Sergiy Bogomolov, and ***Taylor T. Johnson***, "HyRG: A Random Generation Tool for Affine Hybrid Automata," Poster Session, 18th International Conference on Hybrid Systems: Computation and Control (HSCC 2015), CPSWeek 2015, Seattle, Washington, April 2015. Software Tool: `http://verivital.com/hyrg/`

[Po6] Hoang-Dung Tran†, Luan Viet Nguyen†, and ***Taylor T. Johnson***, "Transforming Differential Algebraic Equations (DAEs) to Hybrid Automaton Models for Formal Verification," Poster Session, Texas Systems Day 2015, University of Texas at Dallas, Plano, Texas, March 28, 2015.

[Po5] Leonardo Bobadilla, ***Taylor T. Johnson***, and Amy LaViers, "Towards Verified Planar Formation Control Algorithms by Composition of Primitives," 5th Workshop on Formal Methods for Robotics and Automation Poster Session, Workshop Co-located with Robotics: Science and Systems Conference (RSS), Berkeley, CA, July 12, 2014. [poster pdf] [abstract pdf]

[Po4] Luan Viet Nguyen† and ***Taylor T. Johnson***, "Model-Based Design and Analysis of a Continuous-Culture Bioreactor for Systems Biology Experiments," Texas Systems Day Poster Session, Texas A&M University, College Station, TX, March 28, 2014. [poster pdf]

[Po3] ***Taylor T. Johnson*** and Sayan Mitra, "Verification of Distributed Cyber-Physical Systems: Stability of Digitally Interconnected Linear Systems," Poster Session, Coordinated Science Laboratory 60th Anniversary Symposium, University of Illinois at Urbana-Champaign, Urbana, IL, October 28, 2011. [poster pdf]

[Po2] ***Taylor T. Johnson*** and Sayan Mitra, "Verification of Distributed Cyber-Physical Systems: Stability of Digitally Interconnected Linear Systems," Poster Session, Coordinated Science Laboratory Symposium on Emerging Topics in Control and Modeling: Cyber-Physical Systems, Urbana, IL, October 20, 2011. [poster pdf]

[Po1] ***Taylor T. Johnson*** and Sayan Mitra, "Power Usage of Time and Event-Triggered Paradigms: A Case Study," Poster Session, 15th IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS), CPSWeek 2009, San Francisco, CA, April 13, 2009. [poster pdf]

SOFTWARE TOOLS AND ARTIFACTS

We develop a large amount of research software, particularly verification software tool prototypes, some of which is peer-reviewed through activities such as software repeatability evaluations. Source code for each major artifact is indicated below, and is maintained on the following accounts (Git/Mercurial): `https://bitbucket.org/verivital/`, `https://github.com/verivital`, `https://bitbucket.org/ttj/`, `https://github.com/ttj`.

[S5] SLForge and CyFuzz: Random differential testing for CPS Development Toolchains. This software tool randomly generates CPS model artifacts, currently targeting the MathWorks' Simulink/Stateflow (SLSF). Related papers include [C29,D4,W10]. https://github.com/verivital/slsf_randgen

[S4] HyST: Hybrid Source Transformer. This software tool takes hybrid automaton models in the SpaceEx XML or Compositional Interchange Format (CIF) formats and translates them to other popular hybrid systems verification and reachability analysis tools, including Flow*, dReach, HyComp, HyCreate, and development tools including MathWorks' Simulink/Stateflow (SLSF). Related papers include [C17,C16,C15,C13,D2]. *Best repeatability evaluation award [C17]*. Available online: http://www.verivital.com/hyst/

[S3] Hynger: Hybrid iNvariant GEneratoR: This software tool takes MathWorks' Simulink/Stateflow (SLSF) models, instruments them, and produces traces for dynamic analysis in tools like Daikon. Related papers include [C14]. Available online: http://www.verivital.com/hynger/

[S2] HyRG: Hybrid Random Generator. This software tool randomly generates hybrid automaton models, and is integrated within HyST [S4] to generate models in output formats compatible with several different formal verification tools for hybrid systems. Related papers include [C15,Po7]. Available online: http://www.verivital.com/hyrg/

[S1] Passel: This software tool is used for parameterized verification (sometimes known as uniform verification) of parameterized networks of hybrid automata, and has been used to verify safety specifications in several distributed cyber-physical systems such as proving safe separation in air traffic control protocols. Related papers include [C10,C9,C5,C4]. Available online: https://publish.illinois.edu/passel-tool/

RESEARCH MENTORING (CURRENT)

POSTDOCTORAL RESEARCH SCHOLAR ADVISER

[PD2] 8/2017 – Present: Joel Rosenfeld, Electrical Eng. and Computer Science, Research Topic: Optimization-Based Verification for Cyber-Physical Systems. Research results: [U5,C30].

[PD1] 11/2015 – Present: Weiming Xiang, Electrical Eng. and Computer Science, Research Topic: Unbounded-Time Reachability Analysis for Switched Systems. Research results: [U6,U3,C30,J14,U2,J15,J9,J7,C25,W12,C21,C19].

DOCTORAL DISSERTATION ADVISER

[DS11] Fall 2017 – Present: Tianshu Bao, Electrical Eng. and Computer Science, Vanderbilt University, Dissertation Topic: Reachability analysis of physical dynamics beyond ordinary differential equations (ODEs): partial differential equations (PDEs), delay differential equations (DDEs), differential algebraic equations (DAEs), fractional order differential equations (FDEs), and more.

[DS10] Fall 2017 – Present: Yuanqi Xie, Electrical Eng. and Computer Science, Vanderbilt University, Dissertation Topic: Auto-scribing electronic health records with natural language processing and autosummarization.

[DS9] Fall 2017 – Present: Diego Manzanas Lopez, Electrical Eng. and Computer Science, Vanderbilt University, Dissertation Topic: Safe control synthesis for autonomous cyber-physical systems. Research results: [U2].

[DS8] Fall 2017 – Present: Xiaodong Yang, Electrical Eng. and Computer Science, Vanderbilt University, Dissertation Topic: Symbolic and statistical learning for autonomous cyber-physical systems.

[DS7] Fall 2017 – Present: Patrick Musau, Electrical Eng. and Computer Science, Vanderbilt University, Dissertation Topic: Formal verification of neural networks for autonomous cyber-physical systems. Research results: [U5,U2].

[DS6] Fall 2017 – Present: Ran Hao, Electrical Eng. and Computer Science, Vanderbilt University, Dissertation Topic: Safe reinforcement learning for distributed autonomous robots.

[DS5] Summer 2017 – Present: Nathaniel (Nate) Hamilton, Electrical Eng. and Computer Science, Vanderbilt University, Dissertation Topic: Distributed robotics control synthesis.

[DS4] Summer 2017 – Present: Ayana Wild, Electrical Eng. and Computer Science, Vanderbilt University, Dissertation Topic: Foundations of cyber-physical systems verification. Research results: [U5].

[DS3] Spring 2015 – Present: Hoang-Dung Tran, Electrical Eng. and Computer Science, Vanderbilt University, Dissertation Topic: Formal Verification of Distributed Cyber-Physical Systems. Research results: [U6,J15,J9,J7,W12,C21,C19,W9,W4,J2].

[DS2] Fall 2015 – Present: Shafiul Chowdhury, Department of Computer Science and Eng., University of Texas at Arlington, Dissertation Topic: Randomized Differential Testing for CPS Development Environments. Co-advised with Prof. Christoph Csallner. Research results: [C29,W10].

[DS1] Spring 2014 – Present: Luan Viet Nguyen, Department of Computer Science and Eng., University of Texas at Arlington, Dissertation Topic: Specifications for Cyber-Physical Systems. Research results: [J13,C28,J11,C23,W11,W12,J7,C19,W9,W6,C15,W4,W1,W2,J2].

UNDERGRADUATE RESEARCHERS

Summer 2017 **Yinghui Yang**, *Vanderbilt BSc CS, Project: "Controlling Groups of Swarm Robots with Android Studio and Microsoft Kinect," Vanderbilt University School of Engineering (VUSE) Summer Research Program.*

Summer 2017 **Daniel Hong**, *Johns Hopkins BSc ME, Project: "Controlling Groups of Swarm Robots with Android Studio and Microsoft Kinect," Vanderbilt University School of Engineering (VUSE) Summer Research Program.*

Summer 2017 **Christina Wang**, *Vanderbilt BSc CS, Project: "Controlling Groups of Swarm Robots with Android Studio and Microsoft Kinect," Vanderbilt University School of Engineering (VUSE) Summer Research Program.*

Summer 2017 **Timothy Liang**, *Vanderbilt BSc CS, Project: "Controlling Groups of Swarm Robots with Android Studio and Microsoft Kinect," Vanderbilt University School of Engineering (VUSE) Summer Research Program.*

Summer 2017 **Anissa Alexander**, *Vanderbilt BSc CS, Project: "Controlling Groups of Swarm Robots with Android Studio and Microsoft Kinect," Vanderbilt University School of Engineering (VUSE) Summer Research Program.*

Summer 2017 **Austin Wilms**, *Vanderbilt BSc CS, Project: "Controlling Groups of Swarm Robots with Android Studio and Microsoft Kinect," Vanderbilt University School of Engineering (VUSE) Summer Research Program.*

Summer 2017 **Stirling Carter**, *Vanderbilt BSc CS, Project: "Controlling Groups of Swarm Robots with Android Studio and Microsoft Kinect," Vanderbilt University School of Engineering (VUSE) Summer Research Program.*

RESEARCH MENTORING (PAST / GRADUATED ALUMNI)

POSTDOCTORAL RESEARCH SCHOLAR ALUMNI

[PDA2] 1/2016 – 5/2017: Andrew Sogokon, Electrical Eng. and Computer Science, Vanderbilt University, Research Topic: Liveness Verification for Hybrid Automata. Research results: [C27,C24,C20,C19,W8]. Next position: Postdoc at Carnegie Mellon University.

[PDA1] 3/2016 – 8/2016: Khaza Anuarul Hoque, Department of Computer Science and Eng., University of Texas at Arlington, Research Topic: Formal Verification for Aerospace CPS. Research results: [J13,C22,C18]. Next position: Research Fellow at Oxford University. Current position: Assistant Professor of Electrical Engineering and Computer Science (EECS) at University of Missouri Columbia.

DOCTORAL DISSERTATION ALUMNI

[DA1] Summer 2014 – Summer 2017: Omar Beg, Department of Electrical Engineering, University of Texas at Arlington, Dissertation Topic: Reachability Analysis of Power Electronics and Systems. Co-advised with Prof. Ali Davoudi. Research results: [U4,J11,J10,J6,C26,W11,W7].

MASTER'S THESIS ALUMNI

[MA6] Fall 2015 – Summer 2016: Randy Long, Electrical Engineering, Thesis Topic: Time-Triggered Controller Area Network Design for Formula SAE Racecars and Technique for Measuring CPU Usage on Systems with Nested and Non-Nested Interrupts. Next position: Engineer at Faraday Future.

[MA5] Fall 2015 – Summer 2016: Rahul Kawadgave, Electrical Engineering, Thesis Topic: Automatic Conflict Classification for Vulnerable Road Users. Next position: Engineer at Qualcomm.

[MA4] Fall 2014 – Spring 2016: Nathan Hervey, Computer Science and Eng., Thesis Topic: Distributed Robotics Localization and Control. Next position: Software Engineer at Lockheed Martin.

[MA3] Fall 2014 – Spring 2015: Shweta Hardas, Electrical Engineering, Thesis: "Virtual and Hardware Prototyping of a Modular Multilevel Inverter for Photovoltaics". Next position: Engineer at Cummins.

[MA2] Fall 2013 – Spring 2015: Ruoshi Zhang, Electrical Engineering, Thesis: "Model-Based Design and Analysis of Automotive Systems using Time-Triggered Controller Area Networks (TTCAN)". Next position: PhD student in Electrical Engineering at University of Texas at Arlington.

[MA1] Fall 2013 – May 2015: Amol Vengurlekar, Electrical Engineering, Thesis: "Design of a Real-Time Reconfigurable Bioreactor". Next position: Engineer at EchoStar.

MASTER'S PROJECT ALUMNI

[MP2] Spring 2014 – Spring 2015: Zankar Bapat, University of Texas at Arlington, Electrical Engineering, Project: "Robot Localization with Circle Detection". Next position: Engineer at Ferro Technologies.

[MP1] Fall 2012–Spring 2013, University of Illinois at Urbana-Champaign, Electrical and Computer Engineering: Shamina Shahrin Hossain (first-year graduate student), Project: Verification of Closed-Loop Switching Power Converters (resulted in paper [LC3]).

UNDERGRADUATE RESEARCH PROJECT ALUMNI

[IS3] Summer 2015: Ewin Tang, Major: Mathematics, University of Texas at Austin, Topic: Using the Isabelle Theorem Prover to Prove Some of the Top 100 Formalized Theorems.

[IS2] Fall 2013–Spring 2014, University of Texas at Arlington: Eric Nelson, Project: Xenomai Real-Time Operating System (RTOS) Design for Continuous-Culture Bioreactor (resulted in paper [W2]).

[IS1] Fall 2011, University of Illinois at Urbana-Champaign: Zhongdong Zhu, Project: Simulating Safe and Stabilizing Distributed Cellular Flows (presented in extended version [J3] of paper [C1]).

NSF RESEARCH EXPERIENCES FOR UNDERGRADUATES (REU) PROJECT ALUMNI

[REU2] Summer 2012: Lucas Buccafusca, University of Colorado at Boulder, Project: Safe Distributed Flocking Implemented on the StarL Distributed Robotics Framework. Information Trust Institute, NSF Research Experiences for Undergraduates (REU) Summer Program, University of Illinois at Urbana-Champaign.

[REU1] Summer 2009: Shashank Gupta, Indian Institute of Technology, Kharagpur, Project: Distributed Algorithms for Sensor Networks Implemented on Net-X. Information Trust Institute, NSF Research Experiences for Undergraduates (REU) Summer Program, University of Illinois at Urbana-Champaign.

PROMOTING UNDERGRADUATE RESEARCH IN ENGINEERING (PURE) ALUMNI, University of Illinois at Urbana-Champaign

[PURE10] Spring 2012 (co-advised with Adam Zimmerman): Jordan Kravitz, Project: Distributed Robotics in StarL.

[PURE9] Fall 2011: Akash Kapoor, Project: Reachability Analysis of Power Converters (resulted in paper [LC2]).

[PURE8] Spring 2011: Hershed Tilak, Project: Implementation of a Boundary Detection Algorithm.

[PURE7] Spring 2011: Jeffrey Lale, Project: A Randomized Algorithm for Deadlock-Free Robot Routing.

[PURE6] Spring 2011: Zhihao (Ted) Hong: Modeling Parameterized Power Converters using Timed Automata (resulted in paper [LC2]).

[PURE5] Fall 2010: Hershed Tilak, Project: Simulating Coupled Inverted Pendulums in Matlab.

[PURE4] Fall 2009: Jerry Sun and Dongeek Shin, Joint Project: Simulating a Planar Conveyor System in Matlab.

[PURE3] Spring 2009: Rohan Bali, Project: Simulating Coupled Inverted Pendulums in Matlab.

[PURE2] Spring 2009: Patrick Gu, Project: Extending Giotto to xGiotto on nxtOSEK for Lego Mindstorms.

[PURE1] Fall 2008: Haeran Lee, Soonwoo (Daniel) Chang, Youngho (Ryan) Park, and Yosub Shin, Joint Project: Reachability Analysis of Switched-Mode Power Converters.

SPONSORED RESEARCH SUPPORT

2013 – present **Funded Research Grants, Contracts, and Fellowships**.

Total Research Funding (PI + Co-PI, active and completed projects): $\$25,780,044$

Research Funding as PI: $\$2,555,043$ (Sole PI Share: $\$2,042,606$). Research Funding as Co-PI: $\$23,675,001$. Our research is currently supported by AFOSR, DARPA, the MathWorks, NSA/DoD, NSF, ONR, and Toyota, and past research has been supported by AFOSR, AFRL, ARO, ONR, USDOT, and NVIDIA.

ACTIVE RESEARCH SUPPORT AND PROPOSALS RECOMMENDED FOR SUPPORT

[AG10] Taylor T. Johnson (Co-PI), with Ali Davoudi (PI, UT-Arlington), "Scalable Formal Verification of Resilient Converter-dominated MVDC Networks," Sea and Warfare Weapons(Code 33), Office of Naval Research (ONR), $640,000.00, 3/1/2018 to 2/28/2021, Award Number:N00014-18-1-2184, Role: Co-PI, Duration: 3.00 years..

[AG9] Taylor T. Johnson (Co-PI), with Gabor Karsai, Xenofon Koutsoukos (Co-PI), Ted Bapty (Co-PI), Janos Sztipanovits (Oversight), "Assurance-Based Learning-Enabled Cyber-Physical Systems (ALC)," Assured

Autonomy(AA), Defense Advanced Research Projects Agency (DARPA), $7,200,000.00, 4/2/2018 to 3/31/2022, Role: Co-PI, Duration: 4.00 years..

[AG8] Taylor T. Johnson (Co-PI), with Xenofon Koutsoukos (PI), Janos Sztipanovits (Vanderbilt/EECS), Gabor Karsai (Vanderbilt/EECS), Aniruddha Gokhale (Vanderbilt/EECS), Yevgeniy Vorobeychik (Vanderbilt/EECS), Abhishek Dubey (Vanderbilt/EECS), Maithilee Kunda (Vanderbilt/EECS), Peter Volgyesi (Vanderbilt/EECS), Jennifer Trueblood (Vanderbilt/Psychology), S. Shankar Sastry (Berkeley/EECS), Claire Tomlin (Berkeley/EECS), Anthony Joseph (Berkeley/EECS), Saurabh Amin (MIT/CEE), Nazli Choucri (MIT/Political Science), Alvaro Cardenas (UT Dallas/CS), Bhavani Thuraisingham (UT Dallas/CS), "Science of Security for Cyber-Physical Systems Lablet," Science of Security Lablet(SoSL), Department of Defense (DoD), $14,750,000.00, 9/1/2017 to 8/31/2022, Role: Co-PI, Duration: 5.00 years..

[AG7] Taylor T. Johnson (PI (Sole)), "Understandable and Reusable Formal Verification for Cyber-Physical Systems," Young Investigator Research Program(YIP), Air Force Office of Scientific Research (AFOSR), $437,469.32, 2/1/2018 to 1/31/2021, Role: PI (Sole), Duration: 3.00 years.. Due to contractual issues, I had to re-apply and compete for the AFOSR YIP again, which previously was awarded at UT-Arlington [CG10].

[AG6] Taylor T. Johnson (PI), with Gautam Biswas (Co-PI), Clare McCabe (Co-PI), Julie Johnson (Co-PI), "Improving Participation of Female Computer Science Majors and Professionals through Digital Learning with Groups of Mobile Robots Controlled by Android Apps," MacroGrant, Vanderbilt Institute for Digital Learning (VIDL), $10,000.00, 7/1/2017 to 6/30/2018, Role: PI, Duration: 1.00 years..

[AG5] Taylor T. Johnson (PI), with Christoph Csallner (Co-PI), "SHF: Small: Automating Improvement of Development Environments for Cyber-Physical Systems (AIDE-CPS)," Software and Hardware Foundations, Division of Computing and Communication Foundations, Directorate for Computer and Information Science and Engineering(CISE:CCF:SHF), National Science Foundation (NSF), $498,437.00, 9/1/2015 to 8/31/2018, Award Number:1736323, 1527398, Role: PI, Duration: 3.00 years..

[AG4] Taylor T. Johnson (Co-PI), with Ali Davoudi (PI), David Levine (Senior Personnel), "Real-time Ab Initio Modeling of Electric Machines," Energy, Power, Control, and Networks Program, Division of Electrical, Communications and Cyber Systems, Directorate for Engineering(ENG:ECCS:EPCN), National Science Foundation (NSF), $285,000.00, 8/1/2015 to 7/31/2018, Award Number:1509804, Role: Co-PI, Duration: 3.00 years..

[AG3] Taylor T. Johnson (PI (Sole)), "Cyber-Physical Systems Specification Mismatch and Safe Upgrades," Systems and Software Program(SS), Air Force Office of Scientific Research (AFOSR), $384,259.04, 8/15/2016 to 8/14/2018, Role: PI (Sole), Duration: 2.00 years., transferred to Vanderbilt, previously [AG2].

[AG2] Taylor T. Johnson (PI (Sole)), "Cyber-Physical Systems Specification Mismatch and Safe Upgrades," Systems and Software Program(SS), Air Force Office of Scientific Research (AFOSR), $397,806.87, 8/15/2015 to 8/14/2018, Award Number:FA9550-15-1-0258, Role: PI (Sole), Duration: 3.00 years..

[AG1] Taylor T. Johnson (PI (Sole)), "CRII: CPS: Safe Cyber-Physical Systems Upgrades," CISE Research Initiative Initiative, Cyber-Physical Systems Program, Division of Computer and Network Systems, Directorate for Computer and Information Science and Engineering(CISE:CNS:CRII:CPS), National Science Foundation (NSF), $174,634.00, 6/15/2015 to 6/14/2017, Award Number:1713253, 1464311, Role: PI (Sole), Duration: 2.00 years..

COMPLETED RESEARCH SUPPORT

[CG10] Taylor T. Johnson (PI (Sole)), "Reusable Formal Verification for Cyber-Physical Systems," Young Investigator Research Program(YIP), Air Force Office of Scientific Research (AFOSR), $357,564.00, 8/1/2016 to 7/31/2019, Award Number:FA9550-16-1-0246, Role: PI (Sole), Duration: 3.00 years..

[CG9] Taylor T. Johnson (Co-PI), with Ali Davoudi (PI, UT-Arlington), Frank Lewis (Co-PI, UT-Arlington), Hamidreza Modares (Co-PI, UT-Arlington), "Testbed Acquisition for Resilient Self-Organizing Microgrids," Defense University Research Instrumentation Program(DURIP), Office of Naval Research (ONR), $220,000.00, 9/15/2016 to 9/14/2016, Award Number:N0014-16-1-3180, Role: Co-PI, Duration: 0.00 years..

[CG8] Taylor T. Johnson (Co-PI), with Ali Davoudi (PI, UT-Arlington), Frank Lewis (Co-PI, UT-Arlington), Hamidreza Modares (Co-PI, UT-Arlington), "Realizing Resilient Self-Organizing Microgrids," Department of Defense (DoD) Research and Education Program for Historically Black Colleges and Universities and Minority-Serving Institutions (HBCU/MI)(REP:HBCU/MSI), Army Research Office (ARO), $300,000.00, 9/15/2016 to 9/14/2016, Award Number:N0014-16-1-3180, Role: Co-PI, Duration: 0.00 years..

[CG7] Taylor T. Johnson (PI (Sole)), "Safely and Securely Controlling Large Swarms of Unmanned Aerial Vehicles (UAVs) with the STAbilizing Robot Language (StarL)," Summer of Innovation(SoI), Air Force Research Laboratory (AFRL), $90,000.00, 5/1/2017 to 8/31/2017, Award Number:FA8650-12- 3-7255, Role: PI (Sole), Duration: 0.33 years..

[CG6] Taylor T. Johnson (PI (Sole)), "Formal Modeling of Emergence in Distributed Cyber-Physical Systems," , Air Force Research Laboratory (AFRL), $173,684.00, 8/16/2016 to 4/15/2017, Role: PI (Sole), Duration: 0.66 years., transferred to Vanderbilt, previously [CG5].

[CG5] Taylor T. Johnson (PI (Sole)), "Formal Modeling of Emergence in Distributed Cyber-Physical Systems," Trusted Autonomy and Verification and Validation (V and V), Integrated Command and Control(TAVV), Air Force Research Laboratory (AFRL), $499,546.00, 4/16/2015 to 4/15/2017, Award Number:FA8750-15-1-0105, Role: PI (Sole), Duration: 2.00 years..

[CG4] Taylor T. Johnson (Co-PI), with Stephen Mattingly (PI), Colleen Casey (Co-PI), "App-Based Crowd Sourcing of Bicycle and Pedestrian Conflict Data," University Transportation Center for Livable Communities(TRCLC), United States Department of Transportation (USDOT), $120,001.00, 8/1/2015 to 7/31/2016, Award Number:DTRT13-G-UTC60, Role: Co-PI, Duration: 1.00 years..

[CG3] Taylor T. Johnson (PI (Sole)), "Detecting and Mitigating Cyber-Physical Attacks with Invariant Inference and Runtime Assurance," Summer Faculty Fellowship Program(SFFP), Air Force Office of Scientific Research (AFOSR), $43,575.00, 5/18/2015 to 7/31/2015, Role: PI (Sole), Duration: 0.20 years..

[CG2] Taylor T. Johnson (PI), with Ali Davoudi (Co-PI), David Levine (Senior Personnel), "Real-time Ab Initio Modeling of Electric Machines," Hardware Donation Program(HDP), NVIDIA (NVIDIA), $4,000.00, 11/12/2014 to 11/12/2014, Role: PI, Duration: 0.00 years..

[CG1] Taylor T. Johnson (PI (Sole)), "Inferring Physical System Specifications from Embedded Software Tests," Visiting Faculty Research Program(VFRP), Air Force Research Laboratory (AFRL), $27,980.00, 5/19/2014 to 8/8/2014, Award Number:FA8750-13-2-0115, Role: PI (Sole), Duration: 0.22 years..

CONFERENCE AND OTHER TRAVEL GRANTS

August 2017 **Southeastern Conference (SEC) Faculty Travel Program Award**.

May 2017 **CPS Verification and Validation: Industrial Challenges and Foundations Workshop (CPS V&V I&F Workshop 2017), Carnegie Mellon University (NSF)**.

March 2015 **NSF CISE CAREER Workshop 2015 (NSF)**.

December 2014 **CPS Verification and Validation: Industrial Challenges and Foundations Workshop (CPS V&V I&F Workshop 2014), Carnegie Mellon University (NSF)**.

March 2015 **NSF CISE CAREER Workshop 2015 (NSF)**.

December 2012 **IEEE Real-Time Systems Symposium (RTSS), (University of Illinois at Urbana-Champaign Graduate College and NSF)**.

December 2011 **IEEE Conference on Decision and Control (CDC) (University of Illinois at Urbana-Champaign Graduate College and Rockwell Collins)**.

September 2010 **International Symposium on Stabilization, Safety, and Security of Distributed Systems (SSS) (NSF)**.

December 2009 **IEEE Real-Time Systems Symposium (RTSS) (NSF)**.

April 2009 **IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS) (NSF)**.

OUTREACH

2017 – Present **MNPS K-12 Computer Science Curriculum Development**.

- Developed a mobile phone for computer science curriculum and demonstrations using the Raspberry Pi in conjunction with Chaz Carothers, M.Ed., Encore K-4 Teacher in Metro Nashville Public Schools (MNPS), Advanced Academics Resource Teacher (AART), Henry C. Maxwell Elementary School.

2014 – Present **Rice Association of Volunteer Alumni (RAVA)**.

- Interviewed prospective Rice University undergraduate students and presented during high school college fairs.

2012 – Present **StackExchange and StackOverflow Contributor**.

- Answered over fifty questions related to computer science and programming.
- Contributed extensively to Microsoft Research's Z3 satisfiability modulo theories (SMT) solver questions, and ranked as the top user not employed by Microsoft.

2012 **Demonstrator, Engineering Open House**, *University of Illinois at Urbana-Champaign*, Urbana, IL.
- Spring 2012: Adam Zimmerman, Matt Johnson, ***Taylor T. Johnson***, and Sayan Mitra. Demonstration: Drawing Pictures with Mobile Robots. [video]

2014 – Present **Judge**.
- January 2016: Congressional STEM Competition Mobile App Contest Judge, El Centro College, Dallas County Community College District, Dallas, TX, sponsored by US Congressman Marc Veasey (http://www.house.gov/content/educate/app_challenge/).
- May 2014: Congressional STEM Competition Mobile App Contest Judge, El Centro College West Campus, Dallas County Community College District, Dallas, TX, sponsored by US Congressman Marc Veasey (http://www.house.gov/content/educate/app_challenge/).
- 2014-2015: Computer Science Area Judge, Fort Worth Regional Science and Engineering Fair, University of Texas at Arlington, Arlington, TX.

2007 – 2008 **Mentor for High School Students, DREAM Program**, *Rice University*, Houston, TX.
- Mentored several underrepresented high school students on science and engineering fair projects.

PROFESSIONAL ACTIVITIES AND SERVICE

PROFESSIONAL ORGANIZATIONS

2016 – Present **Member**, *American Association for the Advancement of Science (AAAS)*.

2015 – Present **Member**, *Society of Automotive Engineers (SAE International)*.

2014 – Present **Member**, *American Institute of Aeronautics and Astronautics (AIAA)*.

2005 – Present **Member**, *Institute of Electrical and Electronics Engineers (IEEE)*.

2003 – Present **Member**, *Association for Computing Machinery (ACM)*.

UNIVERSITY AND DEPARTMENTAL SERVICE

2017 – Present **Vanderbilt University, Electrical Eng. and Computer Science, Academic Advisor for a cohort of 25 freshman undergraduates in Computer Science (CS) and Computer Engineering (CmpE)..**

2017 – Present **Vanderbilt University, Electrical Eng. and Computer Science, WithIT Computer Science Seminar Organizer..**

2017 – Present **Vanderbilt University, Ingram Commons, Vanderbilt Visions / VUcept, Faculty VUceptor for a cohort of 18 freshman undergraduates.**.

2017 – Present **Vanderbilt University, VU Women in Science and Engineering and VU Center for Integration of Research, Teaching, and Learning (VU-WiSE and VU-CIRTL) Tiered Mentorship Program (TMP)**, *Participating as a faculty mentor*.

2016 – Present **Vanderbilt University, Graduate Faculty Delegate Assembly (GFDA), Computer Science Representative**.

2016 – Present **Vanderbilt University, Accreditation Board for Engineering and Technology (ABET) Accreditation, Computer Science (CS) and Computer Engineering (CmpE) evaluation development**.

2015 – 2016 **College of Engineering, University of Texas at Arlington, Service and Committees**.
- 2015-2016: Engineering Freshman Interest Group (FIG) Mentor.

2013 – 2016 **Department of Computer Science and Eng., University of Texas at Arlington, Committees**.
- 2015 – 2016: Computer Science and Eng. Faculty Search for Three Tenure-Track Positions, Search Committee.
- 2015 – 2016: Computer Science and Eng. CSE2100: Practical Computer Hardware/Software Systems, Curriculum Committee.
- 2013 – 2016: Computer Science and Eng., Computer Engineering Curriculum Committee.
- 2013 – 2016: Computer Science and Eng. PhD Admissions Committee.
- 2013 – 2016: Computer Science and Eng. Graduate Studies Committee (GSC).
- 2013 – 2016: Computer Science and Eng. Colloquium: invited speakers for over eight invited talks.

2010–2013 **Electrical and Computer Engineering, University of Illinois at Urbana-Champaign**.
- 2010–2013: Incoming Graduate Student Orientation Program Volunteer and Panelist.

2013 – Present **Doctoral Dissertation Committee Membership**.

- 2016 – Present: Fardin Abdi, Electrical and Computer Engineering, University of Illinois at Urbana-Champaign . Adviser: Marco Caccamo. External Committee Member.
- 2016 – Present: Brian Cook, Computer Science and Eng., University of Texas at Arlington. Adviser: Manfred Huber.
- 2015 – Present: John Podolanko, Computer Science and Eng., University of Texas at Arlington. Adviser: Matthew Wright.
- 2014 – Present: Nicholas Brent Burns, Computer Science and Eng., University of Texas at Arlington. Adviser: Gergely Zaruba.
- 2014 – 2015: Seyedali Moayedi, Electrical Engineering, University of Texas at Arlington. Adviser: Ali Davoudi.
- 2014 – 2015: Vahidreza Nasirian, Electrical Engineering, University of Texas at Arlington. Adviser: Ali Davoudi. First position: High-Power Electrical Engineer at TeraDiode, Inc.
- 2013 – Present: Minh Nguyen, Computer Science and Eng., University of Texas at Arlington. Adviser: Hao Che.

2013 – Present **Doctoral Preliminary Exam Committee Membership**.

- 2018 – Present: Tamas Kecskes, Electrical Eng. and Computer Science, Vanderbilt University. Adviser: Akos Ledeczi.
- 2018 – Present: Jiani Li, Electrical Eng. and Computer Science, Vanderbilt University. Adviser: Xenofon Koutsoukos.
- 2016 – Present: Fangzhou Sun, Electrical Eng. and Computer Science, Vanderbilt University. Adviser: Jules White.

RESEARCH REVIEWING AND ORGANIZATIONAL SERVICE

2009 – Present **Reviewing Service Overview and Verified Publons Record**.

My reviewing service for journals and conferences is verified through Publons, and a summary may be seen at: https://publons.com/author/522170/taylor-johnson .

TECHNICAL PROGRAM COMMITTEE MEMBERSHIP

CPS-SR'18 **1st Workshop on Cyber-Physical Systems Security and Resilience (CPS-SR 2018), collocated with CPSWeek 2018, Technical Program Committee, Porto, Portugal, April 2018**.

EMSOFT'18 **18th ACM International Conference on Embedded Software (EMSOFT 2018), Technical Program Committee, Torino, Italy, September-October 2018**.

FAC'18 **9th International Workshop on Frontiers in Analog CAD (FAC 2018), Technical Program Committee, Vienna, Austria, May 2018**.

ICCPS'18 **9th ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS 2018), Technical Program Committee, Cyber-Physical Systems Week (CPSWeek), April 2018**.

HSCC'18 **21st ACM International Conference on Hybrid Systems: Computation and Control (HSCC 2018), Technical Program Committee, Cyber-Physical Systems Week (CPSWeek), April 2018**.

ARCH'18 **5th International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2018), Experimental Evaluation Chair, Cyber-Physical Systems Week (CPSWeek), Porto, Portugal, April 11-14, 2018**.

RTSS-AE'17 **38th IEEE Real-Time Systems Symposium (RTSS), Technical Program Committee, Artifact Evaluation Committee, Paris, France, December 2017**.

EMSOFT'17 **17th ACM International Conference on Embedded Software (EMSOFT 2017), Technical Program Committee, South Korea, 2017**.

V2CPS'17 **2nd International Workshop on Verification and Validation of Cyber-Physical Systems (V2CPS), co-located with the Integrated Formal Methods Conference (iFM 2017), 2017**.

HSCC'17 **20th ACM International Conference on Hybrid Systems: Computation and Control (HSCC 2017), Technical Program Committee, Cyber-Physical Systems Week (CPSWeek), Pittsburgh, Pennsylvania, April 11-14, 2017**.

ARCH'17 **4th International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2017), Experimental Evaluation Chair, Cyber-Physical Systems Week (CPSWeek), Pittsburgh, Pennsylvania, April 11-14, 2017**.

RTSS'16 **37th IEEE Real-Time Systems Symposium (RTSS), Technical Program Committee, Cyber-Physical Systems Track, Porto, Portugal, December 2016**.

EMSOFT'16 **16th ACM International Conference on Embedded Software (EMSOFT 2016), Technical Program Committee, Pittsburgh, PA, October 2-7, 2016**.

ICPP'16 **45th International Conference on Parallel Processing (ICPP 2016), Cyber-Physical Systems Track, Technical Program Committee, Philadelphia, PA, August 16-19, 2016.**

HSCC'16 **19th ACM International Conference on Hybrid Systems: Computation and Control (HSCC 2016), Technical Program Committee, Cyber-Physical Systems Week (CPSWeek), Vienna, Austria, April 11-14, 2016.**

SNR'16 **2nd International Workshop on Symbolic and Numerical Methods for Reachability Analysis (SNR 2016), Technical Program Committee, Cyber-Physical Systems Week (CPSWeek), Vienna, Austria, April 11, 2016.**

ARCH'16 **3rd International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH 2016), Experimental Evaluation Chair, Cyber-Physical Systems Week (CPSWeek), Vienna, Austria, April 11, 2016.**

RTSS'15 **36th IEEE Real-Time Systems Symposium (RTSS), Technical Program Committee, Cyber-Physical Systems Track, San Antonio, TX, December 1-4, 2015.**

RSWeek'15 **Distributed Control Paradigms to Enable Resilient Microgrids, Special Session at IEEE Resilience Week 2015, Co-Organizer, Philadelphia, PA, August 18-20, 2015.**

Compel'15 **16th IEEE Workshop on Control and Modeling for Power Electronics (Compel), Technical Program Committee, Vancouver, BC, Canada, July 12-15, 2015.**

ARCH'15 **2nd International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH), Experimental Evaluation Co-Chair, Cyber-Physical Systems Week (CPSWeek), Seattle, WA, April 13, 2015.**

RV'14 **14th International Conference on Runtime Verification (RV), Toronto, Canada, September 22-25, 2014.**

CONFERENCE ORGANIZATIONAL SERVICE

SNR'18 **4th International Workshop on Symbolic and Numerical Methods for Reachability Analysis (SNR), Co-Chair with Prof. Dr. Martin Fränzle, European Joint Conferences on Theory and Practice of Software (ETAPS), Thessaloniki, Greece, April 14-21, 2018.**

ARCH'18 **5th International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH), Hybrid Systems Verification Competition (HSVC) Repeatability Evaluation Chair and Experimental Evaluation Chair, Cyber-Physical Systems Week (CPSWeek), Porto, Portugal, April 18, 2018..**

ARCH'17 **4th International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH), Hybrid Systems Verification Competition (HSVC) Repeatability Evaluation Chair and Experimental Evaluation Chair, Cyber-Physical Systems Week (CPSWeek), Pittsburgh, PA, April 17, 2017..**

HSCC-RE'17 **19th International Conference on Hybrid Systems: Computation and Control (HSCC 2016), Repeatability Evaluation Program Committee, Cyber-Physical Systems Week (CPSWeek), Vienna, Austria, April 11-14, 2016..**

ICCPS-WiP/Demo/Poster **7th ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS), Work-in-Progress, Demo, and Poster Co-Chair, Cyber-Physical Systems Week (CPSWeek), Vienna, Austria, April 12, 2016..**

ARCH'16 **3rd International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH), Experimental Evaluation Chair, Cyber-Physical Systems Week (CPSWeek), Vienna, Austria, April 11, 2016.**

ARCH'15 **2nd International Workshop on Applied Verification for Continuous and Hybrid Systems (ARCH), Experimental Evaluation Co-Chair, Cyber-Physical Systems Week (CPSWeek), Seattle, WA, April 13, 2015.**

CSL'12 **4th Annual Symposium on Emerging Topics in Control and Modeling: Networked Systems, Coordinated Science Laboratory, University of Illinois at Urbana-Champaign, Urbana, IL, October 15-16, 2012. Organizing committee chair.**

CPSWeek'11 **Cyber Physical Systems Week (CPSWeek) 2011, Chicago, IL. Designed program booklet, which was reused for CPSWeek 2012, Beijing, China..**

JOURNAL REVIEWING

TCS **Elsevier Theoretical Computer Science (TCS), 2017-present**.

AUTOMATICA **Elsevier International Federation of Automatic Control (IFAC) Automatica, 2017-present**.

PIEEE **Proceedings of the IEEE, 2017-present**.

ACM TCPS **ACM Transactions on Cyber-Physical Systems (TCPS), 2016-present**.

IJRNC **International Journal of Robust and Nonlinear Control (IJRNC), 2017**.

IEEE TAC **IEEE Transactions on Automatic Control, 2013-present**.

IEEE CSM **IEEE Control Systems Magazine (CSM), 2016**.

IEEE TPEL **IEEE Transactions on Power Electronics (TPEL), 2016**.

ACM TECS **ACM Transactions on Embedded Computing Systems (TECS), 2015-present**.

IEEE SJ **IEEE Systems Journal, 2014-2016**.

IET CTA **IET Control Theory and Applications (CTA), 2015**.

JSSSE **Journal of Systems Science and Systems Engineering (JSSSE), Springer, 2015**.

JPEDS **International Journal of Parallel, Emergent and Distributed Systems (JPEDS) (previously Parallel Algorithms and Applications), Taylor & Francis, 2015**.

ACM TAAS **ACM Transactions on Autonomous and Adaptive Systems (TAAS), 2012, 2014**.

IEEE JSAC **IEEE Journal on Selected Areas in Communications (JSAC), 2012**.

IEEE TC **IEEE Transactions on Computers, 2009**.

BOOK REVIEWER

Princeton **Princeton University Press, Book Reviewer for Princeton Series in Applied Mathematics, 2017-present.**.

EXTERNAL REVIEWER FOR CONFERENCES

CDC'18 **IEEE Conference on Decision and Control (CDC), 2018**.

PECI'18 **IEEE Power and Energy Conference at Illinois (PECI), 2018**.

ACC'16 **American Control Conference (ACC), 2016**.

ICST'15 **IEEE International Conference on Software Testing, Verification and Validation (ICST), 2015 Tools Track**.

MSC'14 **IEEE Multi-Conference on Systems and Control, 2014**.

PECI'14 **IEEE Power and Energy Conference at Illinois (PECI), 2014**.

ICCPS'13 **ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS), 2013**.

HSCC'13 **ACM International Conference on Hybrid Systems: Computation and Control (HSCC), 2013**.

PECI'13 **IEEE Power and Energy Conference at Illinois (PECI), 2013, 2014**.

HSCC'12 **ACM International Conference on Hybrid Systems: Computation and Control (HSCC), 2012**.

SSS'12 **International Symposium on Stabilization, Safety, and Security of Distributed Systems (SSS), 2012**.

RSS'12 **Robotics: Science and Systems Conference (RSS), 2012**.

HSCC'11 **ACM International Conference on Hybrid Systems: Computation and Control (HSCC), 2011**.

NFM'11 **NASA Formal Methods Symposium (NFM), 2011**.

HSCC'10 **ACM International Conference on Hybrid Systems: Computation and Control (HSCC), 2010**.

2015 – Present **Research Proposal Reviewer**.

- Natural Sciences and Engineering Research Council of Canada (NSERC), External Reviewer, 2017, 2018.
- Mitacs Canada Accelerate Program, External Reviewer, 2017.
- Air Force Office of Scientific Research (AFOSR), External Reviewer, 2015, 2016.
- National Science Foundation (NSF), CISE Review Panels (2015, 2016, 2017, 2018).
- ASEE Science, Mathematics And Research for Transformation (SMART) Scholarship for Service Program, Department of Defense (DoD), Reviewer (2016, 2018).

OTHER REVIEWING SERVICE

2018 – Present **Curriculum Reviewer**.

- National Council of Examiners for Engineering and Surveying (NCEES), Fundamental of Engineering (FE) Exam, Professional Activities and Knowledge Study (PAKS), Survey Creation Committee.

MISCELLANEOUS

Citizenship **US Citizen**.

RESEARCH STATEMENT

My research seeks to answer the challenge: ***"How can we design cyber-physical systems people can bet their lives on?"*** to borrow the words of Dr. Jeannette M. Wing during her time as Assistant Director of NSF's CISE Directorate.[1] To address this challenge, ***my research agenda is to develop and apply formal methods to improve the safety, security, and reliability of cyber-physical systems (CPS)***. CPS are composed of physical and communicating computational processes interacting with each other and their environments. CPS are becoming prevalent in part from the proliferation of devices for computation, communication, sensing, and control, and are the next revolution of embedded systems that will manifest in the coming Internet of Things (IoT).

Unfortunately, we have not yet met this challenge, as ***safety and security flaws are rampant in today's CPS across domains***, including automotive [LC4],[2] medical devices, industrial systems, among many others. As an example, the US NHTSA and other nations' motor vehicle regulatory bodies recalled around 2.5 million cars in 2011 due to one safety-critical design defect.[3] The defect could damage a transmission bearing and cause unexpected vehicle stalls, increasing the risk of crash and injury. This is a ***cyber-physical defect*** that resulted from software in the cyber domain not being appropriately updated due to changes in a component in the physical domain.

Catastrophes may be caused by such cyber-physical defects, many of which arise in extraordinarily complex systems that may incorporate on the order of hundreds of millions of lines of code. ***Unmanned aerial vehicles*** are starting to share increasingly crowded airspace with commercial and passenger air traffic, ***autonomous satellites*** will soon coordinate to form distributed arrangements and service aging satellites, ***networked medical devices*** are being implanted, ingested, and injected in humans, and ***tomorrow's cars*** may drive themselves. However, to realize the societal benefits of these increasingly autonomous CPS, system designers need new abstractions and methods to ensure design correctness and safe operation, as today's are inadequate. In spite of significant challenges, ***I envision a future without expensive and life-threatening safety, security, and reliability flaws in CPS by developing and applying automated formal methods to ensure CPS meet their specifications***, which also alleviates the verification and validation burden that typically dominates CPS development times and budgets.

SUMMARY STATEMENT SINCE JOINING VANDERBILT

During my first three semesters at Vanderbilt, having joined in fall 2016, I have become involved in several activities at Vanderbilt (e.g., VUCept, VUSE Summer Undergraduate Research, a VIDL MacroGrant project, new AFOSR, DARPA, ONR, and DoD/NSA projects, etc.), and set up my research lab and group for the next few years (recruiting 8 new PhD students, 1 new postdoc, and involving 7 undergraduates in research). My ongoing extramural research projects mostly finished their transfers to Vanderbilt (NSF CRII CPS, NSF CCF/SHF, AFRL) and a new AFOSR Young Investigator Research Program (YIP) award was granted (beginning February 1, 2018). For teaching, I prepared and taught 3 new courses (CS6315, CS6375, ES140x) in 2017, substantially revising the curriculum in them all. For service, I reviewed many journal articles, served on around a half-dozen technical program committees, as well serving as NSF review panels, reviewing a book for Princeton University Press, and research proposals for Canadian research agencies (NSERC and Mitacs). For departmental service, I helped with ABET assessment, began serving as an undergraduate academic adviser for a cohort of 25 students, met with several faculty candidates during their visits, including attending dinners with most of them, three of whom joined us (Catie Chang, Jack Noble, and Justus Ndukaife).

Overall, in spite of the significant complexities of a cross-country academic move, both personally and professionally, my research group and I continued our usual academic activities in support of research & scholarship, teaching, and service. For instance, we published a total of 6 journal articles (with 3 more accepted to appear in 2018), 5 referred conference papers (with 2 more accepted to appear in 2018), and 4 refereed workshop papers. My first PhD student, Omar Ali Beg, completed his dissertation and defense and graduated at the end of summer 2017, receiving his PhD in Electrical Engineering from my former institution, UT-Arlington. My second PhD student, Luan Viet Nguyen, published several papers and is on track to graduate from UT-Arlington as well in spring 2018 in Computer Science and Engineering. My third PhD student, Hoang-Dung Tran, has published several papers over the past year, and will sit for his preliminary exam this semester (spring 2018). Both Luan and Tran participated in AFRL's Summer of Innovation program with me at Wright-Patterson in Dayton, OH, giving them experience with governmental research labs. Luan also interned in Toyota's formal methods group in spring 2017. One of my former postdocs, Khaza Hoque, accepted a tenure-track position at an R1 university (University of Missouri). My current postdocs, Weiming Xiang and Joel Rosenfeld, both gained experience in proposal writing, helping me submit a total of 20 proposals, and continued publishing on their research results. They both assisted in developing parts of our upcoming DARPA Assured Autonomy award that is in contracting with an anticipated start in April 2018. In

[1] Jeannette M. Wing, "Cyber-Physical Systems," Computing Research News, CRA, Vol. 21/No. 1, Jan. 2009.
[2] Citations throughout these statements refer to papers, theses, grants, etc. in my enclosed CV.
[3] NHTSA Campaign Number 11V395000, Recall Notice Number 11V-395, Summer 2011.

addition to this, I participated in our successful NSA/DoD Science of Security Lablet, and also submitted a total of 20 new proposals to several agencies (NSF, NIH, ONR, AFOSR, DARPA). During 2017, I also formed a class-C corporation called CelerFama, Inc. as a startup company, with goals to commercialize a pending patent application on automating data entry for electronic health records (EHRs). At the end of 2017, I also formed Verivital, LLC to serve as a central business for future technology transfer and consulting activities. With ISIS, CelerFama submitted an NIH STTR proposal in January 2018, and we are actively pursuing mechanisms for support to further develop our technology. I began collaborating with physicians and researchers in VUMC in support of this direction, submitting a TIPS and now a Discovery Grant on this. In addition, I presented a talk on medical device software safety in VUMC in fall 2017, and have begun building relationships and collaborations for that new direction of my CPS research. Overall, I am satisfied with my research group's progress over the past year, and think our contributions in research/scholarship, teaching, and service speak for themselves at this stage of my career, but I am welcome to suggestions for improvement and critical feedback in any of these areas.

IMMEDIATE PLANS FOR RESEARCH, TEACHING, AND SERVICE

In terms of plans and improvement over the next year, I plan to continue to pursuing extramural support for new projects through agencies such as NSF (CAREER, CPS, SAS, CCF/SHF), DARPA, AFOSR/AFRL, and ONR to mention a few. During 2017, I applied for most early career programs for which I am eligible (NSF Career, NIH, DARPA YFA, ONR YIP, AFOSR YIP), and will continue to target these for which I remain eligible. We have also had some discussions with possible industry support, in particular building on our NSF CCF/SHF project, with the MathWorks, which looks promising as my final PhD student at UT-Arlington, Shafiul Chowdhury, is currently interning with the MathWorks. In addition, we will continue our research progress and publishing our results in prestigious venues, and I will continue to serve the profession through educational, scholarly, and broader societal service, as detailed in my service statement. For teaching, I am performing another new course preparation this semester for Computer Networks (CS4283/5283). After this new course preparation, I plan to continue building on the curriculum and materials developed for other courses to teach them again with changes planned based on student feedback. For instance, I plan to teach ES140x again in fall 2018, with a revision to eliminate AppInventor and use Python as the programming language of choice. Over the next few years, I plan to develop new undergraduate CPS and formal methods courses, as detailed in my teaching statement. As I recruited heavily last year for my research group, at this time I do not anticipate growing my group any larger, beyond involving undergraduates through activities such as the VUSE Summer Undergraduate Research Program and NSF REUs.

OVERVIEW OF PAST RESEARCH AND CONTRIBUTIONS

To achieve ***the vision of safe, secure, and reliable CPS*** on which people can bet their lives, ***my main research focus is to develop and apply methods to verify formally and automatically that CPS and models thereof satisfy their requirements and specifications.*** Specifically, I develop automated formal methods and their implementations in software tools to solve the ***formal verification problem***, which is to prove mathematically that a given formal model of a system satisfies a formal specification. My research draws on—and pushes the frontier of—mathematical tools and techniques from the areas of ***formal methods***, ***hybrid systems***, ***software engineering***, ***control theory***, and ***distributed systems***.

My focus within CPS is on ***hybrid systems***, which combine continuous and discrete states and evolutions, and are useful for modeling CPS, as they capture representative features of modern networked control systems implemented in software on embedded computers. Mathematically, I typically model hybrid systems using ***communicating networks of hybrid automata***, which are essentially state machines extended with sets of real-valued variables with continuous dynamics that evolve over intervals of real-time—modeled by ordinary differential equations [ODEs] or differential inclusions—and that have discrete dynamics—modeled by state machines with discrete transitions. ***I have developed scalable formal methods—modeling frameworks, algorithms, and software tools—for automatically verifying CPS, and I have applied these methods across CPS domains.***

Highlights, Impact, and Significance of Past Research

My past research has impacted two CPS sectors: the ***foundations of CPS*** through theoretical contributions and in ***applications across several CPS domains***. The CPS domains where we have applied our methods range from ***aerospace*** [C4,C5,C6,C9,C8,C16,C12,J5] to ***robotics*** [C1,C2,J1,C7,C11,C12,J3,J4], as well as ***power and energy*** [LC1,LC2,LC3,W1,J2,MA3,J10,J6,U4], ***automotive*** [LC4,MA2,CG4,MA6,MA5,C23,C28], and ***biotechnology*** [W2,MA1]. I have published over sixty papers in prestigious journals, conferences, and workshops on our results to improve CPS safety, security, and reliability across CPS domains. In October 2016, I was ***nominated by AFOSR for the Presidential Early Career Award for Scientists and Engineers (PECASE)*** through my current AFOSR grants [AG2,CG10,AG7] for my contributions. For my proposed CPS research, I received one of four ***NSF CISE Research Initiation Initiative (CRII) awards*** through the CNS/CPS program in 2015 [AG1]. Among my

publications, *two were awarded* ***best paper awards*** *[C5,LC1],* one was awarded an ACM best software repeatability evaluation award *[C17], and another a* ***best CPS research idea award*** *[E1].* While a graduate student at Illinois, I was awarded two endowed fellowships sponsored by Intel and Rambus, as well as an endowed prize for research excellence from Yi-Min Wang of Microsoft Research and Pi-Yu Chung of Oracle.

My dissertation developed the ***first automated method to formally verify safety properties for parameterized networks of hybrid automata*** [C5,C4,C9,C10]. The method relies on our *small model theorem for networks of hybrid automata* proven in one of my award-winning papers [C5], which alleviates ***the state-space explosion problem*** and is the first positive result for parameterized verification of hybrid systems, as prior results indicated impossibility due to decidability barriers. This enabled ***the first automatic formal verification of safe separation between aircraft in the Small Aircraft Transportation Systems (SATS) landing protocol—a component of the FAA/NASA NextGen air traffic control system***—that had previously been verified partly manually using the PVS interactive theorem prover by Dr. Cesar Munoz of NASA Langley. The verification was performed with my *Passel software tool* [S1], which uses *Microsoft Research's Z3 satisfiability modulo theories (SMT) solver*, and Passel is used by researchers from AFRL, George Mason University, Texas A&M, Verimag, among others.

Our ***real-time reachability algorithm for hybrid automata*** is the first of its kind [C11,J4], and is being deployed in avionics systems at NASA Langley by Dr. Alwyn Goodloe and has attracted attention from several industrial partners, such as Bosch through Dr. Thomas Heinz and Toyota through Drs. James Kapinski and Jyotirmoy Deshmukh. The algorithm is attractive because it may be used for monitoring CPS in real-time at runtime so corrective action can be taken if specifications are violated. Our HyST tool [S4,C13,C16,C17,C19,J7,J11,J10] has an ***intermediate representation for hybrid systems to ease automated abstractions***, and is used by researchers from AFRL, Australia National University, UC Boulder, Kansas State University, Freiburg, IST Austria, Illinois, among others. Overall, my contributions include foundational results for *effective modeling abstractions of distributed CPS as networks of hybrid automata*, *scalable formal verification methods for CPS*, and *implementation of these novel verification methods* in publicly available tools, all applied *across CPS domains, including aerospace, robotics, power/energy, and automotive.*

Contributions to Cyber-Physical Systems

Broadly, my research contributions are split between the *foundations of CPS* and across *CPS domains including aerospace, robotics, power/energy, automotive, and biotechnology*, as discussed in more detail next.

Foundations of Cyber-Physical Systems. CPS foundations are in active development, and my research has at its core new ways of thinking about CPS to enable the transformation from classical implementations of control systems in embedded systems to distributed networks of interacting computers controlling geographically distributed physical phenomena. Some of my foundational CPS contributions include the following.

Formal Methods: Formal Specifications for Cyber-Physical Systems: Supported in part by AFOSR [AG2], AFRL [CG5], NSF [AG1], and Toyota, we have developed and applied formal specification languages for describing correct and incorrect behaviors for CPS. Building upon recent foundational work on specifications for multi-trace properties, specifically hyperproperties which are sets of properties (equivalently, sets of sets of traces), we developed a new specification language for hyperproperties for real-valued and real-time signals called HyperSTL that combines signal temporal logic (STL) with hyperproperties [C28]. One interesting observation of this work is that (local) Lyapunov stability is a hyperproperty, and not a property, as an individual trajectory being unstable does not imply a system is not Lyapunov stable. The intuition behind this is that a set of traces are needed to falsify Lyapunov stability, as a single trace may simply not have been in a neighborhood of a region of attraction about an equilibrium point. We have developed methods to falsify STL specifications that also combine frequency-domain information, which are commonly used by controls engineers [C23].

Additionally, we have considered specifications for CPS from a cyber-physical perspective, where each of cyber (such as a software controller), physical (such as a plant), and cyber-physical (such as sensors/actuators) components are subject to specifications over their respective states. With this cyber-physical perspective, we built ***specification inference*** methods to automatically find candidate specifications from CPS models and implementations, specifically within the context of the MathWorks' Simulink/Stateflow (SLSF) [C14,J13]. Mismatches between the specifications of these cyber, physical, and cyber-physical specifications then imply candidate bugs, where a mismatch is defined as the specification between the interfaces of these components being more or less expressive (restricted, constrained) than their connected components. For example, it is common in the software controllers for closed-loop CPS to incorporate information about the plant under control, such as how physical states are sensed and observed through digital to analog conversion (DAC). If a specification change occurs in either the physical system (such as a velocity or other physical state being of greater magnitude than was assumed in the design of the cyber components) or the cyber components (such as a software update or upgrade), then by comparing the restrictiveness of the inferred specifications, we have automatically found possible cyber-physical specification mismatches and bugs [C14,J13].

Distributed Cyber-Physical Systems: Many CPS are distributed computationally and/or physically—such as air-traffic control systems like the FAA/NASA NextGen program or networked autonomous motor vehicles—and I have focused extensively on such distributed CPS. With colleagues, I developed extensions of Leslie *Lamport's happened-before relation* for networks of hybrid automata operating with real-time constraints, and applied these results in *predicate detection algorithms* to establish whether specifications *may* or *must* have been satisfied [C7]. My master's thesis described the first approach for *fault-tolerance in distributed CPS* [E1], which makes it possible to use distributed algorithms like consensus in distributed CPS by building on distributed computing results such as ***failure detectors*** and ***self-stabilization*** [C2,C1,J1,J3]. I have also developed ***new deductive proof methods to establish safety, liveness, and stability properties*** in the context of fault-tolerant distributed algorithms for CPS [C1,J3]. My doctoral dissertation modeled and verified distributed networks of interacting CPS, discussed in more detail next.

Formal Methods: Parameterized Verification for Networked Hybrid Systems: My doctoral dissertation and the related papers [C3,C4,C5,C9,C10] established the ***first positive results for uniform verification of safety specifications in parameterized networks of hybrid automata***, which is frequently known as ***parameterized verification***. In essence, the parameterized verification problem is to prove that a system $A(N)$, which is parameterized on the number of participants, N, satisfies a specification $P(N)$ regardless of the number of participants, i.e., to prove $\forall N \in \mathbb{N},\ A(N) \models P(N)$, where $\mathbb{N}$ is the set of natural numbers. Examples arise in many domains, from ***cache coherence protocols*** in computer architecture to ***mutual exclusion algorithms*** in concurrency and distributed systems. For example, a mutual exclusion algorithm should satisfy the specification that at most a single process is in a critical section simultaneously, formalized as $\forall i, j \in \{1, \ldots, N\} | (i \neq j \wedge q_i = cs) \implies (q_j \neq cs)$, where $q_i = cs$ indicates process i is in the critical section.

For distributed networks of CPS, such as in ***groups of aircraft, cars, or robots***, or in subcomponents like ***clock synchronization algorithms***, a more expressive model of each participant is needed compared to purely discrete ones, so I modeled each participant in the network as a hybrid automaton. In these distributed CPS, a typical safety specification that arises is collision avoidance, which is formalized as a physical dual of classic mutual exclusion: $\forall i, j \in \{1, \ldots, N\} | (i \neq j) \implies ||x_i - x_j|| \geq s$, where x_i represents a position of participant i in some Euclidean space (e.g., $\mathbb{R}^3$), s is a positive real indicating some safe amount of spacing between participants, and $|| \cdot ||$ is the Euclidean norm. While existing negative results showed it was undecidable to solve this problem algorithmically, my approach developed a *small model theorem* that showed, under some mild assumptions, that there exists a finite (and often small) bound $N_0 \in \mathbb{N}$ that suffices to prove $A(N) \models P(N)$ holds for all N if $A(N_0) \models P(N_0)$ [C5]. More technically, the "small" in the small model theorem refers to the size of satisfying assignments (models) of formulas from a certain class of syntactically-restricted multi-sorted first-order logic used to encode inductive invariance proof conditions.

I applied this theoretical result in conjunction with heuristic ***invariant synthesis and abstraction procedures*** implemented in my publicly-available Passel software tool [S1] that uses Microsoft's Z3 SMT solver to automate ***inductive invariance proofs*** to verify numerous realistic systems, from real-time mutual exclusion algorithms to the FAA/NASA NextGen SATS landing protocol [C9]. Liveness verification is also possible by finding ***ranking functions***. These results may enable automatic verification in other distributed CPS arising in the Internet of Things (IoT), such as networked medical devices, swarm robots, or vehicle-to-vehicle communications in motor vehicles.

Formal Methods: Reachability Analysis and Model Checking for Hybrid Systems: Our research has made contributions to ***reachability analysis and model checking for hybrid systems*** of various classes. I developed new reachability techniques that ***exploit symmetries*** in networks of hybrid automata, ***significantly alleviating the state-space explosion problem by orders of magnitude*** compared to other approaches, addressing a fundamental challenge in applying model checking [C10]. With collaborators from the University of Toronto, I developed new ***bounded model checking (BMC)*** methods for hybrid automata using a new quantified encoding, which built upon BMC results for purely discrete systems that used quantified Boolean formula (QBF) solvers instead of SAT solvers [W6]. With Dr. Stanley Bak of AFRL's Information Directorate, I developed ***the world's first reachability algorithm for hybrid systems that may be implemented with real-time guarantees*** due to its novel features and no reliance on external libraries, and we implemented it on several embedded platforms to illustrate its real-time capabilities, such as ARM and Arduino processors [C11,J4].

Also with AFRL collaborators, I developed an ***intermediate representation for hybrid systems***, as well as its implementation in the publicly available HyST software tool [S4], which makes comparing different model checking and verification approaches significantly simpler, and helps lead to a science of CPS with fair comparisons and reproducible research results [C13,C19]. More fundamentally, we have also developed and implemented novel abstraction procedures and transformation passes for the hybrid systems intermediate representation in our HyST tool, such as ***continuization*** [C16], ***hybridization*** [C17], and ***order reduction*** [J7]. ***Continuization*** transforms a nonlinear hybrid automaton into a purely continuous system such that all the behaviors of the original hybrid

automaton may be matched in the continuous system (i.e., it is a sound abstraction) [C16]. ***Hybridization*** transforms a nonlinear continuous system, or a hybrid automaton, into another hybrid automaton with simpler continuous dynamics that is often easier to analyze [C17]. ***Order reduction*** takes a system with n real-valued state variables and transforms it into another system with k real-valued state variables such that $k \ll n$, and is a typical approximation used in control for which we have developed guaranteed error bounds for formal verification [J7]. Overall, the HyST effort may someday lead to something akin to "llvm for hybrid systems," where generic (language agnostic) transformation passes ease the verification burden, similar to how llvm has helped progress in compilers and in verifying compiler optimizations.

Cyber-Physical Systems Domains. In addition to CPS foundations and theory, my research is applied across CPS domains, including aerospace, robotics, power and energy systems, automotive, and biotechnology.

Aerospace Systems: In addition to the ***FAA/NextGen air traffic control verification*** aforementioned [C4,C9], I have worked extensively in verifying aerospace systems in collaboration with AFRL and NASA. With Dr. Scott Erwin of AFRL's Space Vehicles Directorate, I developed methods to ***automatically verify conjunction (collision) avoidance in autonomous groups of satellites*** orbiting Earth and ***eventual rendezvous of satellites*** when desired, and also established the impossibility of solving this problem using reachability analysis by relating it to results in mathematical billiards [C6]. Our recent work to detect cyber-physical specification mismatches was inspired by classic aerospace software failures, such as Ariane 5's flight 501, and may lead to ways to compose systems safely that is an even greater challenge today [C14,J13]. With Dr. Stanley Bak of AFRL's Information Directorate, I developed the first reachability algorithm with real-time guarantees now being ***deployed in avionics systems*** by Dr. Alwyn Goodloe of NASA Langley [C11,J4], and we also developed automated abstraction methods to analyze real-time control systems, with application to ***yaw damper control systems in passenger jets*** [C16].

Robotics: My earliest research has applications in swarm robotics, where geographically and computationally distributed groups of robots communicate and coordinate to meet some objectives, such as forming a flock and reaching a goal location, while maintaining some safety specifications, such as collision avoidance, all in the presence of failures [C2,C1,J1,J3]. Recently, with collaborators from the University of Virginia and Florida International University, I developed distributed algorithms for formation control building upon previously verified primitives [C12]. One example is our ***planar formation control algorithm that combines high-level specifications written in linear temporal logic (LTL) with a verified one-dimensional flocking algorithm***, and allows for exponentially convergent formation of shapes such as wedges, vees, and general open kinematic chains, all while avoiding collisions [C12].

Power and Energy Systems: I have a long-running interest in power and energy systems, which began during my time as an intern at Schlumberger, the world's largest oilfield services company. For example, I wrote software deployed in the world's first downhole sampling-while drilling tool while at Schlumberger, which resulted in a publication that ***won a best paper award*** [LC1] and ***resulted in a patent*** [P1]. In power and energy, I have published on using ***adaptive control in motor control*** [LC1], *reachability analysis* and model checking of open-loop ***power electronics*** [LC2], reachability analysis of closed-loop power electronics [LC3,C14], and the design of a *novel DC-to-AC architecture for interfacing DC-producing renewable energy sources like photovoltaics to the AC grid* [J2,MA3]. I have released publicly available power and energy benchmarks to the hybrid systems community to help create scientific, fair, and reproducible comparisons between different formal verification approaches [W1,W7,C26]. Most recently, I have shown how to use formal approaches such as reachability analysis in the context of typical ***model validation for power electronics***, which formally quantifies the similarity between experimental data recorded from power converters with mathematical models and with computer-based simulation models in SPICE and PLECS [J10,J6].

Automotive Systems: With colleagues from the University of Waterloo, I showed rates of motor vehicle recalls in the US, Canada, and Europe due to defects in computer-related components (termed electrical and electronics [E/E] components in the ISO 26262 functional safety standard for road vehicles) are increasing [LC4]. This work was presented at the NHTSA's 24th International Technical Conference on the Enhanced Safety of Vehicles (ESV), and *highlighted to regulatory bodies in attendance such as the NHTSA, Transport Canada, and Europe's RAPEX the impending computer-related safety and security problems in motor vehicles* [LC4]. To help address these issues in automotive, I collaborate with UTA's Formula SAE racecar team, and identified and corrected several bugs in their automotive systems that use controller area networks (CAN) [MA2,MA6]. Additionally, one of my PhD students, Luan Nguyen [DS1], spent two research internships in the formal methods group of Toyota, where we applied our foundational results on cyber-physical specifications to engine control problems [C23,C28].

Biotechnology: I collaborate with systems biologists at UT-Southwestern studying evolution. We designed custom laboratory equipment (a continuous-culture bioreactor), which reduced the cost compared to commercial solutions by two orders of magnitude, and improved the reliability of an initial prototype by using the Xenomai real-

time operating system (RTOS) patch to the Linux kernel. The system uses the Beaglebone Black ARM development board with several printed circuit boards (PCBs) we designed to control peristaltic pumps [W2,MA1].

COMPLETED SPONSORED RESEARCH PROJECTS

We have completed several research projects from sponsors such as AFRL [CG5], AFOSR [CG10], and USDOT [CG4], a summary of which is discussed next. *I collaborate with sociologists and civil engineers to improve road transportation safety*, especially for vulnerable road users such as cyclists and pedestrians, with a traffic conflict detection system [CG4,MA5].

Completed Research: Emergent Behavior in Distributed Cyber-Physical Systems

Complex distributed CPS may have *emergent behaviors* that spontaneously arise at runtime. We aim to prove the absence of undesired emergent behavior or to prove the presence of desired emergent behavior through this project sponsored by AFRL [CG5]. One example of possibly desired emergent behavior is flocking and collision avoidance in groups of distributed robots. An example of undesired emergent behavior includes possible cyber or physical attacks or failures that may result in unstable oscillatory movement of robots or catastrophic mission failure. Our approach is rooted in formal methods, with the perspective that ***emergent behavior may be desired or undesired, so long as all expected behaviors are specified***, so undesired emergent behavior is just any unexpected behavior. We classify emergent behaviors using formal specifications, then check system models to determine whether they meet these specifications or not. We use ***runtime monitoring and verification*** building on our real-time reachability results [C11,J4], heuristics-based techniques building on our specification inference results in Hynger [C14,S3], and extensions of the *Simplex architecture to distributed CPS* building on self-stabilization [J3] and failure detectors [J1]. In part based on work in this project, we developed ***hyperproperties for real-valued and real-time signals in an extension of Signal Temporal Logic (STL) called HyperSTL***, extending recent results on hyperproperties for software systems that are discrete-state and discrete-time [C28], which allows for formalizing common properties in CPS—such as Lyapunov stability—that are not expressible in temporal logics over individual traces, such as STL.

ONGOING RESEARCH AND PLANNED RESEARCH DIRECTIONS

Currently, I am focusing on several active research projects related to CPS foundations and CPS applications, sponsored by AFOSR [AG2,AG7], DARPA [AG9], DoD/NSA [AG8], and NSF (CISE CCF/SHF [AG5], CISE CNS/CPS [AG1], and ENG ECCS/EPCN [AG4]).

Ongoing Research: Cyber-Physical Specification Mismatch and Safe CPS Upgrades

I am working to solve a classic problem in CPS, which is how to ensure systems are upgraded safely across versions, and am sponsored by NSF and AFOSR to develop complementary methods [AG1,AG2]. In these projects, we focus on *upgrades of cyber and physical components in CPS*, as well as the reuse of legacy components. We take the perspective that such ***upgrades are actually specification changes***, i.e., upgrades of cyber and/or physical components—such as when legacy subcomponents are reused in new systems or new versions—***are defined by changes in the specifications of requirements the systems should satisfy***. In conjunction with colleagues from AFRL where I started developing these ideas through my 2014 VFRP fellowship at AFRL [CG1], we formalized ***cyber-physical specification mismatches***, which are roughly when specifications in the cyber and physical domains do not agree, in the sense that they are more or less restrictive than one another [C14,J13]. Our approach aims to detect and mitigate the effects of cyber-physical specification mismatches at design time and at runtime.

As an example, *the root cause of the Ariane 5 flight 501 crash in the mid-90s was essentially a cyber-physical specification mismatch*. In this failure, an inertial measurement unit (including its software) from Ariane 4 was reused in Ariane 5, even though Ariane 5 had drastically different physical operating requirements. The software of this subcomponent had an assumption about the physical environment encoded. The assumption was essentially that a velocity was bounded, which would have prevented a software variable from overflowing (and apparently did in Ariane 4). However, because the trajectory of Ariane 5 was drastically different from that of Ariane 4, this implicit velocity bound was exceeded and the variable overflowed, which eventually led to the computers crashing and the rocket failing catastrophically. Thus, ***the cyber components had encoded invalid assumptions about the physical system and physical operating environment that led to the failure***. Other recent examples of this same type of cyber-physical specification mismatch include the 2011 recall of around 2.5 million cars aforementioned, so such critical problems still exist across CPS domains. Many CPS are used over years-to-decades-long lifespans, are subject to frequent cyber-physical design reuse, and have the potential for cyber-physical specification mismatch when upgraded. Addressing the intersection of legacy system integration into futuristic CPS is a problem that has gone unresolved for decades as illustrated by failures like Ariane 5 and recent recalls of medical devices and motor vehicles.

My approach is inspired by formal methods and models subcomponents as ***hybrid input/output automata (HIOA)***, the specifications in formal temporal languages, and mismatches as satisfiability modulo theories (SMT) problems. We use *dynamic analysis to find specifications of CPS from traces generated from tests*. A prototype tool

called Hynger [S3] has been developed that takes arbitrary Simulink/Stateflow (SLSF) diagrams, instruments them, and generates traces for dynamic analysis tools such as *Daikon* to infer specifications (candidate invariants) [C14,J13]. In the future we plan to consider broader classes of specifications beyond invariants, and may draw inspiration from methods such as Angluin's L* learning. Our general technique is being applied more broadly also to *identify anomalies in CPS*, which could be due to *cyber attacks*, *unmodeled behaviors*, *failures*, etc. The cyber attack perspective was considered during my 2015 AFOSR SFFP at AFRL's Information Directorate [CG3], where we *successfully detected and mitigated a false data injection attack in an electrical distribution microgrid*, such as what is commonly found in aircraft electric power distribution networks where there are multiple sources (generators) and loads. The unmodeled behaviors perspective is being pursued in my AFRL project on trusted computing, where we aim to ensure CPS have only those behaviors that have been specified and do not have any emergent behaviors at runtime [CG5], discussed next.

Ongoing Research: Automating Improvement of Development Environments for CPS (AIDE-CPS)

We aim to ***automatically identify defects in widely-used CPS development environments such as the MathWorks' Simulink/Stateflow (SLSF)*** through this project sponsored by NSF [AG5]. Our approach builds on recent results from programming languages/compilers and addresses many technical issues in developing related techniques for CPS development environments, such as SLSF. In particular, we are pursuing a similar ***randomized differential testing*** approach used in the CSmith project that found hundreds of real bugs in widely used compilers such as llvm and GCC that were subsequently corrected. In our approach, CPS models and artifacts are randomly generated, compiled/translated (possibly using different compilers or code generators), executed (in some way, such as through simulation or reachability analysis) using different simulation engines or tools, and subsequently compared. If the results differ, then a tool in some stage of the CPS development process may have a bug. ***Through this approach, we have found dozens of real bugs that have been corrected by the MathWorks in SLSF that could have resulted in wrong code generation, which could result in bugs arising in deployed CPS, and our results have been published at ICSE 2018, the top software engineering conference [C29].***

Defining the notion of difference between results is a key technical contribution, as is the random generation of hybrid automata and of dataflow models such as SLSF diagrams. Overall, this effort may lead to automatic ways to test code generators, compilers, simulation engines, and verification tools, all of which make up modern CPS development environments.

In addition to this main effort to automate bug finding in CPS development environments, we are striving to ***improve reproducibility of research results in CPS and hybrid systems***. Reproducibility of research results is an essential part of the scientific process, which is sometimes strayed from in the search for novelty and publishable results. This project is co-funded by the Venture Fund for Software Reuse of NSF's CISE/ACI Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21). Our work directly contributes to the vision of the CIF21 initiative, which is to provide software as enabling infrastructure for science and engineering research and education. The core contribution to this vision thus far is our HyST software tool [S4,C13] which has an ***intermediate representation*** to describe hybrid systems models and specifications. In essence, the input of HyST is a network of hybrid automata in a certain format (the SpaceEx XML format), which is parsed into an intermediate representation in HyST's internal data structures. The output of HyST is the model syntactically and semantically translated and transformed to support other CPS and hybrid systems tools (currently dReach, Flow*, HyComp/nuXmv/HyDI, HyCreate, and Simulink/Stateflow). Researchers from Illinois are adding support for the C2E2 tool and researchers from IST Austria are adding support for the XSpeed tool, with other research groups from Kansas State University, Verimag, and elsewhere having expressed interest in supporting their tools in HyST.

HyST is at the core of all of our active research projects, and in addition to aiding the hybrid systems community, has drastically improved the productivity of my group, as it is very easy to create benchmark comparisons for the supported tools [W4]. Eventually, ***HyST may lead to quantitative and objective comparisons of model checking and formal verification methods for hybrid systems, which will help create a science of CPS***, similar to how quantitative computer architecture was enabled by standardized input formats and benchmarks, such as the SPEC Benchmarks, and how significant progress has been made in SMT solvers with SMT-LIB. I also help organize the Applied Verification for Continuous and Hybrid Systems Workshop (ARCH) at CPSWeek 2015, 2016, and 2017 to create curated benchmarks, where I serve as the Evaluation Chair. Through ARCH, participants from industry, such as Bosch and Toyota, have contributed industry-grade problems that researchers are now working to solve, and our group has also contributed extensively to the collection of benchmarks [W1,W4,W3,W7,W8,W9,W12,W11]. Additionally, building on these benchmarks, we hosted the 1st Hybrid Systems Verification Competition at CPSWeek 2017 where I served as the repeatability evaluator [W13], which had 13 competitors and served as a first instantiation of a competition to advance hybrid systems verification, similar to competitions in areas such as SAT, SMT, and software verification.

Ongoing Research: Other Projects

In addition to the projects described above where I serve as PI, I am co-PI on other projects through NSF [AG4,CG4]. With Dr. Ali Davoudi at UTA, I am investigating fundamental approaches to modeling power electronics and electric machines using high-fidelity models based on *ab initio* (first principles) physics [AG4]. Our goal is to improve modeling fidelity and real-time analysis capabilities, building on fundamentals of order-reduction for high-order models of power/energy CPS [J10,J6,U4]. We have an upcoming ONR award building on these directions to ensure safe and secure operation of electrical microgrids [AG10].

Future Research Plans and Plans for Research Sponsorship

Currently, I am focused on my ongoing sponsored projects related to CPS foundations and applications in aerospace, automotive, and robotics. In the future, I plan to continue my efforts in CPS foundations and in CPS domains such as aerospace, robotics, and power/energy, but also to increase my efforts in ***CPS security foundations*** and in both ***medical and automotive CPS***. We have some preliminary projects and results in automotive CPS done with UTA's Formula SAE racecar team and Toyota [MA2,LC4,CG4,MA6,C23,C28], and we have been pursuing projects through DARPA, NSF, USDOT, and SRC to secure intra and inter-vehicular automotive networks. To specify security, we are building upon our HyperSTL language for specifying security constraints as hyperproperties over real-time and real-valued signals, in addition to typical discrete-time and discrete-state hyperproperties through HyperLTL where such an abstraction makes sense [C28]. For inter-vehicular networks, I plan to formally verify vehicle-to-vehicle network protocols such as DSRC for security and real-time guarantees. For intra-vehicular networks, such as CAN, I plan to develop a ***verified control system stack***, starting with low-level verified components, such as the verified Cambridge ARM ISA, layering the verified seL4 microkernel (or eChronos RTOS) above, and then developing verified control system programs at the network and application layers, which will build on our hybrid systems verification methods. This may yield a verified control system stack that has the ***highest safety and security guarantees***. Towards this goal, I attended DARPA's first seL4 Developer's Day in 2015 and am collaborating with NICTA to deploy the verified seL4 microkernel in automotive systems, starting with the Formula SAE racecars at UTA [MA2,MA2,MA6].

In my four years as a faculty member, ***I developed significant experience in leading successful proposals, and have been awarded a total of*** 19 ***funded research grants, contracts, fellowships, and gifts as PI or co-PI***. In the future, I plan to continue pursuing support for my research through NSF, DoD, other federal agencies, state agencies, and industry, and to continue pursuing interdisciplinary projects. In addition to the successful proposals that I led or co-led for a total of nineteen awards, I led UTA's 2015 NSF Partnerships for International Research and Education (PIRE) limited-submission proposal, which focused on cyber-security in intra and inter-motor vehicle networks, which progressed to the final round at NSF but was not awarded (after a preliminary panel review at NSF and an internal competition at UTA). This $\sim$ \$5 million proposal was entitled "PIRE: SECuring automotive ComputAtion with foRmal layerS (SEC-CARS)," and included domestic researchers from Illinois and international researchers from McMaster, McGill, NICTA, and Waterloo, and had an advisory board from Bosch, Toyota, the MathWorks, Texas Instruments, NASA, and DARPA. This proposal formed the basis of my 2017 NSF CAREER proposal that is in review on developing formal specification and verification tools for security in intra and inter-vehicular networks of motor and aerospace vehicles. Beyond this and my sponsored projects, I have also led or co-led proposals to AFOSR, AFRL, DARPA, NIH, NSF (CNS/CPS, CRISP, MRI, SaTC STARRS), ONR, TxDOT, Google, and Microsoft.

For research sponsorship in the next few years, while I plan to continue my collaborative efforts, ***I will focus on early career opportunities***, as having finished my PhD in 2013, I am eligible and will pursue programs such as NSF CAREER, NIH Director's New Innovator Award Program (DP2), ONR Young Investigator Program (YIP), DARPA Young Faculty Award (YFA), and Army Research Office Young Investigator Award (YIA). Of these, I have been awarded the AFOSR YIP twice [AG7,CG10], but have chances remaining in programs that have limitations, so I will focus on these over the next few years before my eligibility expires. In addition to these early career and young investigator programs that solicit applications, I was nominated by AFOSR in October 2016 for the PECASE, which comes with substantial support if awarded.

For potential industry collaboration and sponsorship, I have built an extensive network of contacts in many CPS domains including aerospace (Boeing, Lockheed Martin, Raytheon, Rockwell Collins, and UTC/UTAS), automotive (Bosch, Denso, GM, and Toyota), computer-aided design (Cadence, IBM, MathWorks, Mentor Graphics, Microsoft, National Instruments, SRC, and Synposis), industrial systems (GE and UTC/BIS), and semiconductors (ARM, Freescale, Intel, NVIDIA, Qualcomm, and Texas Instruments). Of these, for example, the MathWorks is very interested in our AIDE-CPS project [AG5] and has agreed to provide support for investigating bugs that we may find in their products, which aided in the success of our recent ICSE paper [C29], whose lead author [DS2] currently interns with the MathWorks. ***In the coming years, more CPS domains will mandate the use of rigorous design***

methods encouraging the use of formal methods and there will be increased certification efforts. This trend is in part due to new standards—such as in medical device development through IEC 62304, in aerospace through DO-178C and DO-333, and in automotive through ISO 26262—as well as recent high-profile recalls, such as the 2011 NHTSA recall aforementioned and the 2015 NHTSA recall for the remote attacks on Jeeps by Charlie Miller and Chris Valasek. The FDA already solicits software safety research for medical devices, the USDOT (via NHTSA and FHWA) is starting projects in automotive software and security research, NASA and FAA support formal methods in CPS, NIST has a CPS program, and many industrial firms developing CPS need high reliability, so there are ample opportunities for both sources of challenging problems to advance the start-of-the-art in CPS as well as funding. As Vanderbilt University Medical Center (VUMC) is a top medical institution with many researchers developing novel medical devices, particularly surgical robotics through the Vanderbilt Institute for Surgical Engineering (VISE), I have begun preliminary collaborations with VUMC faculty in software safety for medical devices [IT28] and plan to continue this direction in the future.

TEACHING STATEMENT

The opportunity and privilege to teach and mentor are primary motivations for my pursuit of a career in academia. ***Teaching results in everyone—students, professors, humanity—knowing more, due in part to the bidirectional feedback between student and teacher, as well as between research and teaching, all of which together enhance each other.*** Teaching and mentoring are perhaps the most rewarding duties of professorial life, and I have successfully fulfilled these roles in the past, and continue to do so today. Overall, I expect my students and mentees to accomplish things greater than myself so that humankind makes progress in the pursuit of knowledge, understanding, and innovation, and of course, have fun doing so. For them to achieve this, I equip them with fundamental knowledge and the best skills and tools, so they may turn their own goals and dreams into reality during their lifetimes of learning. ***My experience teaching and mentoring students across diverse domains from computer science, electrical/computer engineering, and systems engineering illustrates my dedication to these goals, as well as to the broader vision to develop a workforce with the necessary education to design cyber-physical systems (CPS) on which people can bet their lives.***

FUTURE COURSES, TEACHING PHILOSOPHY, AND TEACHING EXPERIENCE

During my four years as a faculty member, ***I have taught hundreds of undergraduate and graduate students through ten courses as the primary instructor of record, and I have substantially developed curriculum to the state-of-the-art in every course***. Of these ten courses, *four were at the undergraduate level* and *six were at the graduate level*. Individual mentoring of students to successful completion of their research and degree requirements is an essential responsibility as a faculty member. ***I currently advise two postdoctoral research associates, eleven PhD students, and several undergraduate researchers, and have supervised one PhD alumnus [DA1] and six MSc thesis alumni*** [MA4,MA5,MA6,MA3,MA2,MA1]. Additionally, ***I have a long history of commitment to teaching, and helped teach six courses as an undergraduate teaching assistant while at Rice, as well as three courses as a graduate teaching assistant at Illinois***. I also created computer science material and video lectures for UTA's "Introduction to Engineering and Engineering Mathematics" course, which was an ***EdX massive open online course (MOOC) taken by thousands of students*** with the goal to introduce high school students to engineering careers and enhance their math skills. In fall 2018, Coursera will launch a MOOC as a part of a Distributed Systems module composed of 4 courses, with one course taught by myself, two by Profs. Andy Gokhale and Abhishek Dubey at Vanderbilt, and the final course taught together as a capstone.

In the future, I would enjoy teaching a variety of undergraduate and graduate-level engineering and computer science courses, such as those that I have already taught (discussed in more detail below), as well as compilers, distributed systems, control systems, embedded/real-time systems, logic, and automata theory/theory of computation. In the longer term, ***I plan to further develop new graduate and undergraduate courses in systems and software engineering for embedded systems and CPS, as well as an undergraduate formal methods course***. Based in part on my industry experience, I believe there is a need for an ***undergraduate CPS course for students across computer science and engineering disciplines*** (electrical/computer, industrial/systems, and mechanical/aerospace). Such a course will focus on the design, modeling, analysis, and implementation of CPS using modern, standard tools like the MathWorks' Matlab/Simulink or NI's LabView, real-time operating systems, practical electronics and mechanical design, and appropriate embedded hardware. This will facilitate an appreciation of the challenges software engineers face when developing software in actual control systems underlying modern CPS, as well educate computer science students in control theory and engineering, so that these diverse domains have a common language to express their ideas and challenges. This will also instill collaborative and cross-disciplinary design practices in the engineers of tomorrow who will be designing CPS that need increasingly high reliability as more functions become automated with little-to-no human control, or in some cases, even supervision.

I appreciate constructive criticism provided by teaching assessments, as it helps me reflect on my teaching to become a more effective instructor. ***Feedback in both directions of the learning process—from the teacher to the student through prompt graded assignments and from the student to the teacher through assessments—identifies areas to improve for the students and professor, so everyone may learn and perform better.*** It is very difficult to try to reach all students in a class, given their different education levels and backgrounds. It is essential to reiterate material seen in lecture in other activities such as discussion sections, homeworks, and labs, which ensures the diverse body of students understanding and appreciating the material. I frequently use ***early feedback assessments in the first weeks of a course*** to help me evaluate how I am doing as well as the class's background, which helps identify what changes I must make to be the most effective teacher possible, while there is still sufficient time in a course to make changes. While students may need guidance to understand material, I believe they learn the most making discoveries themselves, so I help them, but do not just fill them with answers to regurgitate. To paraphrase, ***students are candles to be lit, not bottles to be filled***, so I

strive to instill a thirst for knowledge and passion for discovery in humanity's pursuit of understanding.

Current Course: Computer Networks (Vanderbilt CS 4283 / CS 5283) In spring 2018, I am teaching a cross-listed undergraduate/graduate course on computer networks. Through this course, we assume a basic operating systems background, then describe computer networks using the OSI and TCP/IP layered models, followed by discussions of UDP, TCP/IP, routing in the Internet through protocols like BGP, various other networking IETF RFCs, then several wireless networking protocols and media including Bluetooth, Zigbee, and IEEE 802.11. This will be my first time teaching networks, so I look forward to learning this material to a greater extent by teaching the course, as it ties in well with my research foci around networked distributed cyber-physical systems. We will also illustrate upcoming networking advances such as vehicle-to-vehicle (V2V) communications with DSRC, and gaining a greater understanding in the operation of such protocols will allow me to understand whether there is a need for verification in such protocols and what challenges may need to be addressed to do so.

Past Courses: Introduction to Engineering, Computer Science Modules (Vanderbilt ES 140x: ES1401, ES1402, ES1403) Over fall 2017, I taught one of two sections of computer science modules for Vanderbilt's Introduction to Engineering (ES 140x) course, which is required for all engineering majors, after redesigning the curricula with Prof. Julie Johnson, my co-instructor who taught the other section. My involvement in this course began in part through a women in computing initiative I lead at Vanderbilt [AG6], where we are attempting to replicate Harvey Mudd's success in increasing the percentage of women computer science majors from around twenty percent (our current rate) to around forty to fifty percent. One of the three pillar's in Harvey Mudd's successful initiative was in recreating introductory computer science courses, which is what we have attempted to do through this course redesign. The modules are broken into three distinct one-hour courses lasting around a month each over the semester, and students select modules such as computer science, mechanical engineering, etc. based on their interests. In this course, we introduced students both to fundamental computer science concepts and software programming assuming no prior knowledge of programming, although some students did have prior experience from high-school courses, typically in Java. To help level the playing field, we used a graphical programming language called AppInventor from MIT, which is used to develop Android apps, and for which our informal surveys in class indicated 1 of 75 students had previously seen the language. The course culminated in students developing apps to control iRobot Create mobile robots to reproduce shapes drawn on the Android device in the physical world, using a Bluetooth connection between the Android device and a Raspberry Pi connected to the iRobot Create through a serial port.

Overall, the vast majority of students succeeded in this project, which we found impressive given the about one month duration of the course. The structure of this course was divided into four assignments: the first was a basic app to introduce concepts of data structures such as lists, variables, iteration, events, and procedures, followed by an app to draw pictures on the Android device. These assignments were followed by two apps to (1) modify the drawing app so that when a complex shape (e.g., a square) was selected from a set of possible shapes to draw, it was drawn in a reactive systems fashion and took some amount of real-time to draw, mimicking the amount of actual time it would take the robot to move with forward and rotational velocities, and then (2) the final app to have the robot reproduce the drawn picture by moving around its physical environment driven by actuation commands from the Android app. The fundamental computational and cyber-physical thinking concepts introduced ranged from syntax/semantics, variables, iteration, recursive data structures such as lists, induction, reactive systems, basic networking, embedded systems, sensing/actuation, open-loop control, and closed-loop feedback control.

Past Courses: Discrete-Event Systems: Supervisory Control and Diagnosis (Vanderbilt CS6375) In fall 2017, I taught a discrete-event systems course in part using Cassandras and Lafortune's "'Introduction to Discrete Event Systems"' 2008 book (2nd edition). In this course, after introducing requisite background material on logic, set theory, etc., we covered numerous discrete-event systems models and classes of time and state (e.g., continuous vs. discrete), such as finite state automata (FSAs, NFAs, DFAs), transition systems, regular expressions, formal languages, discrete-time Markov chains (DTMCs), continuous-time Markov chains (CTMCs), differential equations, and hybrid automata. We discussed a variety of fundamental analysis questions, such as reachability analysis for safety and repeatability analysis for liveness, and briefly introduced some model checking tools such as nuXmv and Spin, and also studied the relationships between trace-based and language theoretic definitions and analyses. We elucidated throughout the course the unifying theme of all these classes of models, that their operational semantics may be defined in terms of executions or traces, intuitively conceptualizing these as sequences of states, much like time-series data of a simulation.

Past Courses: Automated Verification (Vanderbilt CS 6315) and Automated Software Engineering (UTA CSE 6323): In spring 2017 and fall 2015, I taught a graduate course in automated formal methods (CS 6315: Automated Verification at Vanderbilt and CSE 6323: Automated Software Engineering at UTA). We used Prof. Rajeev Alur's 2015 textbook *"Principles of Cyber-Physical Systems,"* which introduces CPS through a

formal methods approach and discusses core automated software engineering algorithms, such as LTL model checking with reachability and repeatability analyses. In the course, we explore numerous automated formal methods tools, including the nuXmv/NuSMV model checker, Microsoft Research's Z3 SMT solver, Frama-C, and the Spin model checker. The curriculum for the course is based on the SE 5302 course I taught at the University of Connecticut, discussed next.

Past Courses: Formal Methods (SE 5302 at the University of Connecticut): In summer 2015, I developed and taught formal methods as an adjunct instructor to about thirty engineers in industry who were geographically distributed—a third from each of the US, Europe, and Asia. The course was ***all online and was part of the United Technologies Corporation (UTC) Institute for Advanced Systems Engineering (IASE)*** at the University of Connecticut. I was sought out to teach this course based on my expertise in formal methods for CPS. This synergistic teaching activity *allowed me to instill the latest concepts in engineers practicing in industry designing safety-critical CPS, such as the elevators, fire alarm systems, and avionics systems produced by UTC subsidiaries such as Otis, Kidde, and UTAS, as well as to learn about the latest industry challenges and needs.* We incorporated guest lectures from UTC employees and from the MathWorks, who respectively described UTC's perspective on formal methods, and the latest formal methods tools that are integrated within Matlab and Simulink/Stateflow (such as abstract interpretation with Polyspace and model checking with Simulink Design Verifier), which is widely used in industrial CPS development. In the teaching evaluations, 15 of 26 students responded for a response ratio of 58% yielding a median overall rating of my teaching of 5.0 out of 5.0, and 12 of the 15 respondents stated they learned "more" or "much more" in this course than in other courses.

Past Courses: Mobile Systems Engineering (UTA CSE 4340 and CSE 5349): In spring 2015, I created one elective undergraduate computer engineering course on mobile systems using ***the perspective of distributed computing theory to provide a foundation***, but also incorporating modern practical development tools and practices, such as using Java for Android mobile devices in Android Studio and using version control with Git on GitHub. We fundamental distributed systems concepts such as ***Lamport's happened-before relation, partial orders, and canonical distributed algorithms (clock synchronization, leader election, consensus, mutual exclusion, predicate detection, Paxos, and the recent Raft consensus algorithm)***. For programming assignments, we used an Android framework called StarL for programming distributed algorithms for deployment to Android devices controlling mobile robots, and we used ***rapidly exploring random tree (RRT) algorithms for path planning***. In their projects, *students programmed groups of mobile robots to communicate and use distributed coordination to solve a problem akin to a distributed traveling salesman problem*, where robots had to visit sequences of waypoints in environments with obstacles, and deadlocks could occur if distributed coordination was not performed properly.

Past Courses: Cyber-Physical Systems (UTA CSE 6359): In spring 2014, I created and taught one graduate research-oriented interdisciplinary engineering course around my core research expertise of CPS. The course enrolled 9 students, about half from CSE and half from EE. The course was divided into two main parts, first a lecture component where I covered material on CPS, followed by an interactive paper and project presentation component, and from the teaching evaluations, the students greatly enjoyed this format. We first studied the latest developments from real-time/embedded systems, control theory, software engineering, and communications/networking using a free textbook for the course by Profs. Ed Lee and Sanjit Seshia, *"Introduction to Embedded Systems - A Cyber-Physical Systems Approach,"* followed by student-led projects and presentations. For teaching evaluations, there was a 100% response rate, with my instructor effectiveness average of 4.8 out of 5.0 with a 0.3 standard deviation.

Past Courses: Computer Organization and Assembly Language Programming (Vanderbilt CS 2231 and UTA CSE 2312): During fall 2016, 2014, and 2013, I taught the sophomore-level computer organization and assembly course required for all Vanderbilt CS/CmpE and UTA CSE undergraduates. I redeveloped the course using modern methods and tools such as ***QEMU, ARM assembly, and gdb***, and the latest 5th edition of Profs. David Patterson and John Hennessy's *"Computer Organization and Design: The Hardware/Software Interface."* I implemented substantial changes from the status-quo for this course, such as utilizing a different instruction set architecture (ISA), ARM, which I believe is easier to understand and of more relevance today. Overall, the department has partially adopted my redesign, and ***my materials from fall 2013 and fall 2014 have been reused in a total of seven sections taught by other instructors*** in spring 2014, summer 2014, fall 2014, spring 2015, summer 2015, and fall 2015. My teaching evaluations for fall 2014 were above university averages, where 24 of 46 students responded with my average instructor effectiveness rating of 4.4 out of 5.0, with a standard deviation of 0.7. Some student comments from my evaluations include:

- "He always introduced new topics in a comprehensive manner, and did lots of review to ensure we knew the material. The homework assignments were detailed and were a good study tool. He is a very good communicator."
- "He did really well with teaching the course. The examples that he did in class really helped, and allowed for me to

pay attention more."

- "He tried his hardest to make information interesting and answered all of our questions. We alwasy [sic] reviewed what we had gone over from the privous [sic] lecture so the information stayed fresh and we could answer his questions. Over all I really enjoed [sic] the professor and the class."
- "The early information was easy, when the programming started it was difficult, but there are many resources the professor makes available, also he is easy to communicate with when you go to his office hours or email him."
- "The programming assignments contributed a lot to my understanding of assembly. I felt they were fair."

SERVICE STATEMENT

Service in academia involves commitment to the profession, the scholarly community, our students, our organizations (universities, schools/colleges, departments, professional societies), and the broader community that we serve through our teaching and research ideally for the betterment of society as a whole. With this philosophy in mind, I have undertaken numerous service responsibilities and opportunities.

Service to the Profession, the Scholarly Community, and Industry

As indicated in my CV, I actively serve as a reviewer for prestigious research journals of the ACM, IEEE, and other publishers, as well as on the technical program committees of prestigious computer science and engineering conferences. In addition to this standard form of scholarly service, I have helped organize several research events, including conferences, workshops, and symposia. I continue to serve the research community by reviewing proposals and serving on review panels for agencies such as NSF. Beyond my own scholarly community, I have had the opportunity to serve as a reviewer for the curriculum tested in the NCEES licensure exams, such as the Fundamentals of Engineering (FE) exam, required in the United States for professional licensure as an engineer.

Service to Students

The opportunity to serve our students is one of the greatest pleasures of academia. With this perspective, I have served as an academic adviser at Vanderbilt for a cohort of 25 computer science undergraduates, and previously as a Freshman Interest Group engineering mentor while at UT-Arlington. As my own undergraduate experience at Rice involved frequent engagement with faculty, facilitated in particular by Rice's Residential Colleges, I serve as a VUceptor for Vanderbilt Visions organized through the Ingram Commons helping 18 freshman transition to college life and Vanderbilt. To help with our current enrollment surge in computer science, in fall 2017 I also volunteered to teach an extra section of ES140x Introduction to Engineering modules for freshman, and based in part on student feedback, will revise the curriculum further when I teach it again in fall 2018. While at Vanderbilt, I have involved 7 undergraduates in research in part through the VUSE Summer Undergraduate Research Program, and also serve on 4 EECS doctoral preliminary exam committees. I have also been participating as a faculty mentor for the VU Women in Science and Engineering and VU Center for Integration of Research, Teaching, and Learning (VU-WiSE and VU-CIRTL) Tiered Mentorship Program (TMP). As women are underrepresented in computer science and engineering, both professionally and as students, I have begun an effort to recruit and retain women in computing, in part supported by a VIDL MacroGrant, with our approach building on a successful approach employed at Harvey Mudd that increased the percentage of women CS undergraduate majors from around 20% to over 40%. This initiative involves (1) revising introductory courses, which I have done with ES140x, (2) involving undergraduates in research early, which I have done through the VUSE Summer Undergraduate Research program, and (3) emphasizing the societal impact of computing, which I have done in part through teaching ES140x and preparing curricular materials as a part of our VIDL MacroGrant. Previously, I have served the broader scientific and engineering community by judging app design contents sponsored by the US Congress, as well as regional science and engineering fairs.

Service to Organizations

At all the organizations with which I have been affiliated through employment or professional society means, I have had the pleasure to serve these organizations. For example, at Vanderbilt I serve on university and departmental committees, including participating in EECS ABET reviews, organizing the EECS WithIT seminars, and previously served on several committees, including faculty search committees, at UT-Arlington.

Service to Society

Through several activities, I have had the opportunity to serve society both through academia-related activities and more broadly through community service. This has been through aiding in college fairs for high school students, and interviewing prospective undergraduates for Rice University through the Rice Alumni Volunteer Association (RAVA). I have helped an MNPS teacher, Chaz Carothers, prepare curriculum for K-4 students to program a mobile phone using the Raspberry Pi. For communicating research and help to the broader computer community, I actively contribute questions and answers to help websites such as StackExchange and StackOverflow, which students and professionals alike routinely query when solving problems. While at Vanderbilt, I have helped prepare portions of the ABET review for CS and CmpE. My family and I are active members of our church organization (St. Bartholomew's Episcopal Church), and I have served as a volunteer helping improve the grounds and playground for the church and associated school.