# Jun Chai | Curriculum Vitae

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## Research Interests

Modeling, stability analysis, invariance safety analysis, robust control, event-triggered controller design, and numerical simulation of nonlinear and hybrid systems with applications to power systems and robotics.

## Education

**University of California, Santa Cruz**                                    **Santa Cruz, CA**
*Ph.D. in Computer Engineering, (Expected graduation June 2018)*                    *2014–present*
Dissertation Title: Analysis and Design of Algorithms for Forward Invariance and Safety of Hybrid Systems

**University of Arizona**                                                   **Tucson, AZ**
*M.S. in Mechanical Engineering, 4.0*                                           *2012–2014*
Thesis Title: Invariance Tools For Hybrid Dynamical Systems.

**University of Arizona**                                                   **Tucson, AZ**
*B.S. in Mechanical Engineering, 3.8*                                           *2009–2012*
Senior Design Project: Robust Measurement Technique for Rotating Shafts

## Professional Experience

**Graduate Student Researcher**                                             **2014–present**
*Hybrid Systems Lab, University of Santa Cruz*                                   *Santa Cruz, CA*
Analyze, design controllers with safety guarantees, and simulate (in MATLAB & Simulink) hybrid dynamical systems and cyber-physical systems via model-based invariance and event-triggered techniques

**Graduate Research Assistant**                                             **2012–2014**
*Hybrid Dynamics and Controls Lab, University of Arizona*                         *Tucson, AZ*
Modeled, developed and implemented control algorithms on power generation in microgrids (DC/AC inversion, DC/DC conversion)

**Safety Engineering & Virtual Tech-Crash Lab, SAIC Motor Technical Center  Summer 2012**
*Intern Laboratory Assistant/Interpreter*                                       *Shanghai, China*
Assisted professional researchers to design and to perform safety tests for SAIC vehicles; simulated vehicle crash experiment using FEM softwares; host chapter vehicle safety law discussions; interpreter vehicle safety documents to Chinese

**Undergraduate Research Assistant**                                        **2011-2012**
*Hydrodynamics Laboratory, University of Arizona*                                *Tucson, AZ*
Build several small scale models of solar tower design and performed experiments on these models in subsonic wind tunnel and water tanks, including data acquisition, processing and analysis

## Honors

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|---|---|
| **2017-2018 Chancellor's Dissertation-Year Fellowship** | **Santa Cruz, CA** |
| *UCSC Jack Baskin School of Engineering* | *2017* |
| **Computer Engineering Summer 2016 Fellowship** | **Santa Cruz, CA** |
| *UCSC Computer Engineering Dept.* | *2016* |
| **Best Presentation in Session Award** | **Portland, OR** |
| *IEEE American Control Conference* | *2014* |
| **Aerospace and Mechanical Eng. Department Graduate School Fellowship** | **Tucson, AZ** |
| *University of Arizona* | *2012-2013* |
| **Voltaire Design Award** | **Tucson, AZ** |
| *Senior Design, University of Arizona* | *2012* |
| **Graduate with Honor** | **Tucson, AZ** |
| *Honor College, University of Arizona* | *2012* |
| **Dean's List** | **Tucson, AZ** |
| *University of Arizona* | *2009–2012* |

## Teaching & Mentoring Experience

**2016**: Lecturer – Workshop on Hybrid Control Systems    *Conf. on Decision and Control, Las Vegas NV*

**2015–2016**: TA – Discrete Mathematics (CMPE 16)    *U.C., Santa Cruz, CA*

- Duties included: Grading exams, creating exam and homework solutions, lecturter of weekly discussion sessions, manage course website and hold weekly office hours

**2015**: Mentor – UCSC undergraduate capstone project (CMPE 129)    *U.C., Santa Cruz, CA*

- Duties included: Advise on implememtation of control algorithms for microgrid; attend weekly team discussions

**Summer 2015**: Mentor – UCSC Science Internship Program (SIP)    *U.C., Santa Cruz, CA*

- Duties included: Mentoring highschool interns on the implemtation and simulation (MATLAB & Simulink) of power generation in microgrids

**2013**: TA – Introduction to Dynamics (AME 250)    *University of Arizona*

- Duties included: Grade exams and homeworks, hold office hours weekly
- Topics included: Dynamics of particles and rigid bodies as applied to mechanical systems

**2012**: TA – Dynamics of Machines (AME 352)    *University of Arizona*

- Duties included: Grade exams and homework assignments, hold office hours weekly, and administering exams and team projects
- Topics included: introduction of basic methods in the synthesis and kinematic and dynamic analysis of mechanisms commonly encountered in machine design; graphical and algebraic methods to design and analyze basic linkages; applications of the analytical results; balancing of rotating machinery and the dynamics of single and multicylinder internal combustion engines

## Theses

### Doctorate of Philosophy in Computer Engineering

**title**: *Analysis and Design of Algorithms for Forward Invariance and Safety of Hybrid Systems*

**supervisor**: Dr. Ricardo G. Sanfelice

**abstract**: Forward invariance properties for sets that are robust to disturbances are introduced for hybrid systems modeled in the hybrid inclusions framework. Notions and sufficient conditions for sets to enjoy such property for controlled hybrid systems, via given static state-feedback laws, are presented. Furthermore, a result on existence of such state- feedback laws using robust control Lyapunov functions (RCLFs) is established. State- feedback laws using two selection theorems are proposed to accomplish the invariance- based control goals for the class of hybrid systems considered. Applications and numerical simulations in power systems are given to illustrate major results.

### Master of Science in Mechanical Engineering

**title**: *Notions and Sufficient Conditions for Forward Invariance in Hybrid Dynamical Systems*

**supervisor**: Dr. Ricardo G. Sanfelice

**abstract**: Properties of forward invariance for hybrid dynamical systems are studied. Such systems are defined by differential and difference inclusions with constraints. Four forward invariance notions and corresponding sufficient conditions for them to hold are introduced. Lyapunov-based conditions are proposed to estimate a weakly forward invariant set of a given hybrid system. The results are illustrated in examples. Moreover, the presented forward invariance property is used to design a hybrid controller for a single-phase DC/AC inverter. The designed controller is found to be robust to small perturbations and variation of the input voltage. Numerical simulations are included to illustrate the results.

### Bachelor of Science in Mechanical Engineering

**title**: *Robust Measurement Technique for Rotating Shafts*

**supervisor**: Dr. Burhan Hamdan

**abstract**: Design and built an external housing and battery device to increase the Unit Operational Testing Life (UOTL) of the Accumetrics AT-5000 telemetry system at the Caterpillar Inc. Proving Ground in Tucson, which functions as a wireless data acquisition and transmission device from a rotating shaft. The design product is used in conjunction with an integrated timer circuit to maximize the test data acquisition time to 2 to 3 weeks from 20 hours. Moreover, the design prototype is tested to be safely operated under 180 F temperatures and can be installed by a single test technician in under 5 minutes. The total expenditures design is under budget and met all of the major requirements as imposed by various stakeholders.

## Publications

### Journal Articles

**[4]**: J. Chai, P. Casau, and R. G. Sanfelice. Analysis of Event-triggered Control Algorithms using Hybrid Systems Tools, *Automatica*, (in preparation)

**[3]**: J. Chai, and R. G. Sanfelice. On Robust Controlled Forward Invariance of Sets for Hybrid Dynamical Systems, *IEEE Transactions on Automatic Control*, (under review)

**[2]**: J. Chai, and R. G. Sanfelice. A Robust Hybrid Control Algorithm for a Single-Phase DC/AC Inverter with Variable Input Voltage, *IEEE Transactions on Circuits and Systems*, (in preparation)

**[1]**: T. A. F. Theunisse, J. Chai, R. G. Sanfelice, and M. Heemels. Robust Global Stabilization of the DC-DC Boost Converter via Hybrid Control, *IEEE Transactions on Circuits and Systems*, vol. 62, pp. 1052–1061, April, 2015.

Peer–Reviewed Conference Proceedings........................................................................

**[7]**: J. Chai, P. Casau, and R. G. Sanfelice. Analysis of Event-triggered Control Algorithms using Hybrid Systems Tools, To appear in *Proceedings of the 56th IEEE Conference on Decision and Control*, 2017.

**[6]**: J. Chai, and R. G. Sanfelice. On Robust Forward Invariance of Sets for Hybrid Dynamical Systems, In *Proceedings of the American Control Conference*, pp. 1199–1204, 2017.

**[5]**: J. Chai, and R. G. Sanfelice. Results on Feedback Design for Forward Invariance of Sets in Hybrid Dynamical Systems, In *Proceedings of the 55th IEEE Conference on Decision and Control*, pp. 622–627, December, 2016.

**[4]**: J. Chai, and R. G. Sanfelice. On Notions and Sufficient Conditions for Forward Invariance of Sets for Hybrid Dynamical Systems, In *Proceedings of the 54th IEEE Conference on Decision and Control*, pp. 2869-2874, December, 2015.

**[3]**: J. Chai, and R. G. Sanfelice. Hybrid Feedback Control Methods for Robust and Global Power Conversion, In *Proceedings of the 5th Analysis and Design of Hybrid Systems*, pp. 298–303, October, 2015.

**[2]**: J. Chai, and R. G. Sanfelice. A Robust Hybrid Control Algorithm for a Single-Phase DC/AC Inverter with Variable Input Voltage, In *Proceedings of the American Control Conference*, pp. 1420–1425, 2014.

**[1]**: T. A. F. Theunisse, J. Chai, R. G. Sanfelice, and W.P.M.H. Heemels. Hybrid Control of the Boost Converter: Robust Global Stabilization, In *Proceedings of the 52th IEEE Conference on Decision and Control*, pp. 3635–3640, 2013.

Patent.....................................................................................................................

**[1]**: R. G. Sanfelice and J. Chai. Robust single-phase DC/AC inverter for highly varying DC voltages, *US Patent* pending, USC-160/US, 14/879630, 2017.

# Presentations

Oral Presentations......................................................................................................

**[6]**: Event-triggered Control and Analysis via Hybrid Systems Tools, *HSL review day* UCSC, CA, August 2017

**[5]**: On Robust Forward Invariance of Sets for Hybrid Dynamical Systems, *American Control Conference* Seattle, Washington, USA, May 2017

**[4]**: Results on Feedback Design for Forward Invariance of Sets in Hybrid Dynamical Systems, *Conference on Decision and Control* Las Vegas, Nevada, USA, December 2016

**[3]**: Forward Invariance of Sets for Hybrid Dynamical Systems *HSL review day* UCSC, CA, July 2016

**[2]**: On Notions and Sufficient Conditions for Forward Invariance of Sets for Hybrid Dynamical Systems *Conference on Decision and Control* Osaka, Japan, December 2015

**[1]**: A Robust Hybrid Control Algorithm for a Single-Phase DC/AC Inverter with Variable Input Voltage *American Control Conference* Portland, Oregon, USA, June 2014

### Poster Presentations

**[5]**: Hybrid Feedback Control Methods for Robust and Global Power Conversion *Baskin School of Engineering Open House*, Santa Cruz, California, USA, March 2017

**[4]**: Hybrid Control Algorithms for Robust Power Conversion in Smart Grids *CITRIS @ UC Santa Cruz Open House*, Santa Cruz, California, USA, April 2016

**[3]**: Hybrid Control Algorithms for Robust Power Conversion in Smart Grids *12th Annual Graduate Research Symposium*, Santa Cruz, California, USA, April 2016

**[2]**: Hybrid Feedback Control Methods for Robust and Global Power Conversion *UCSC Research Review Day*, Santa Cruz, California, USA, October 2015

**[1]**: Hybrid Feedback Control Methods for Robust and Global Power Conversion *CITRIS Day 2015*, Berkeley, California, USA, October 2015

### Lectures/Workshops

**[4]**: Workshop on Feedback Control of Hybrid Systems *2016 IEEE Conference on Decision and Control*, Las Vegas, Nevada, USA, December 2016

**[3]**: Lecture on Applied Discrete Mathetics for CMPE 16: Introduction on Induction Proofs, *UCSC* Santa Cruz, CA, 2016

**[2]**: Lecture on Dynamics of Machines for AME 352: Graphical and algebraic methods to design and analyze basic linkages, *UA* Tucson, AZ, 2012

**[1]**: STEM - Engineers in Classrooms, *Mission View Elementary School* Tucson, AZ, 2012

## Academic Service Work

**Computer Engineering Graduate Student Society**                                    **UC Santa Cruz**
*Steering Committee, Santa Cruz, CA*                                                              *2017*

**IEEE CSS Technical Committee on Hybrid Systems**
*Member*                                                                                                      *2017*

**College of Mechanical Engineering**                                    **Technoligy University of Taiyuan**
*Publicity Office Manager, Taiyuan, China*                                                    *2007-2009*

## Grant Writing Experience

**Safety Control Algorithms in Robotics using Hyrbid Systems Tools**
*2017 - 2018 Chancellor's Dissertation-Year Fellowship, 2016*
Sole Author, *Status: Accepted*

**Robust single-phase DC/AC inverter for highly varying DC voltages**
*NSF Innovation Corps - National Innovation Network Teams Program (I-CorpsTM Teams), 2015*
Sole Author, *Status: Canceled*

**Robust Measurement Technique for Rotating Shafts**
*University of Arizona, Honors College, 2012*
Team Author, *Status: Accepted*

## Professional Activities

- **Reviewer** of technical papers submitted to the journals: IEEE Transactions on Automatic Control; IEEE Transactions on Signal Processing; Automatica; Elsevier Nonlinear Analysis: Hybrid Systems; IEEE Access.
- **Reviewer** of technical papers submitted to the conferences: IEEE Conference on Decision and Control; IEEE American Control Conference; ACM International Conference on HSCC.

## Outreach and Volunteer Activities

**Volunteer: Trail Building at Teaching Rock**                    **Pinnacles National Park**
*Pinnacles Climber Appreciation Day, Pinnacles National Park, CA*                    *Oct 2017*

**Volunteer: Adopt-a-crag Glen Canyon**                    **Glen Canyon State Park**
*Bay Area Climbers Coalition, San Francisco, CA*                    *Apr 2017*

**Judge: Field Competition**                    **Santa Clara, CA**
*VEX Robotics State Championship*                    *Feb 2017*

**Lecturer: Hybrid System Lab: Intro. to Feedback Control**                    **UC Santa Cruz**
*Girls in Engineering*                    *July 2016*

**Volunteer: Adopt-a-crag Goat Rock**                    **Castle Rock State Park**
*Bay Area Climbers Coalition, Saratoga, CA*                    *Apr 2016*

**Sales and Interpretor**                    **Las Vegas, Nevada, USA**
*AAPEX/Sema Show*                    *2014 - 2017*

**Panelist: Graduate Student Researcher Panel**                    **UA**
*AME 485s: Colloquium*                    *Oct 2013*

**Lecturer: Engineering Field**                    **Mission View Elementary School**
*STEM - Engineers in Classrooms*                    *Feb 2012*

**Voluntary Counselor**                    **University of Arizona**
*Camp WildCat*                    *June 2010*

**Volunteer; Vise Manager of Outreach Office**                    **Technoligy University of Taiyuan**
*The Screw House Volunteers Association*                    *2007 - 2009*