Shalom D. Ruben

CONTACT

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AREAS OF INTEREST

Control and system theory; Design, modeling, and control of mechatronic systems; Optimization theory and embedded optimization; Computer Vision used in feedback control or Visual Servoing; Taking advantage of the GPU for fast embedded algorithms; Robotics as a mechanism for technology education; Audio Engineering, Analog Synthesizers, and Software Defined Radios (SDR) as tools for teaching Signals and Systems

EDUCATION

University of California at Los Angeles, Los Angeles, CA
Doctor of Philosophy, Mechanical Engineering 2010

University of Washington, Seattle, WA
Master of Science, Mechanical Engineering 2002

University of Washington, Seattle, WA
Bachelor of Science, Mechanical Engineering 2000

ACADEMIC APPOINTMENTS

Teaching Professor 2023– Present
Mechanical Engineering Department
and Electrical, Computer, and Energy Engineering Department (by courtesy)
University of Colorado at Boulder, CO

Associate Teaching Professor 2018– 2023
Mechanical Engineering Department
and Electrical, Computer, and Energy Engineering Department (by courtesy)
University of Colorado at Boulder, CO

Assistant Teaching Professor 2012 – 2018
Mechanical Engineering Department
and Electrical, Computer, and Energy Engineering Department (by courtesy)
University of Colorado at Boulder, CO

Adjunct Professor 2012
Electrical Engineering Department
Colorado School of Mines, Golden CO

Adjunct Professor Winter 2011
Mechanical and Aerospace Engineering Department
University of California at Los Angeles (UCLA), Los Angeles CA

Postdoctoral Research Associate 2011 – 2012
Electrical, Computer, and Energy Engineering Department (ECEE)
University of Colorado at Boulder, CO

Postdoctoral Program Participant Fall 2010
"Modern Trends in Optimization and Its Application"
Institute for Pure and Applied Mathematics (IPAM), Los Angeles, CA

TEACHING EXPERIENCE

Instructor, University of Colorado

- Optimal Design (MCEN 4125/5125) 2013 - 2024
- System Dynamics (MCEN 4043) 2012 - 2024
- Feedback Control (MCEN/ECEN 4138/5138) 2018 - 2023
- Industrial Automation (MCEN 4228/5228) 2014 - 2023
- Advanced Linear Systems (MCEN/ECEN 5448) 2022
- Introduction to Computer Vision (MCEN 4228/5228) 2017 - 2018
- Senior Design (MCEN 4045) 2015 - 2018
- Computational Methods (MCEN 3030) 2014 - 2016
- Linear and Integer Programming (Coursera MOOC) 2013 - 2016
- Control Systems Laboratory (ECEN 4638) 2011, 2014
- Statics and Structures (MCEN 2023) 2015
- Dynamics (MCEN 2043) 2014
- Component Design (MCEN 3025) 2012 - 2013
- Introduction to Engineering (GEEN 1500) 2012
- Signals and Systems (ECEN 3300) 2012

Instructor, Colorado School of Mines

- Introduction to Feedback Control Systems (EGGN 307) 2012

Instructor, UCLA

- Digital Control of Physical Systems (MAE 171B) 2011
- Teaching Assistant Training Seminar (MAE 495) 2007–2009
- Intro to Programming and Numerical Methods (MAE 20) 2004 – 2006

Teaching Assistant, UCLA

- Intro to Modeling and Analysis of Dynamic Systems (MAE107) 2008
- Intro to Feedback and Control Systems (MAE 171A) 2004, 2006
- Engineering Acoustics (MAE153A) 2004

Teaching Assistant, University of Washington

- Kinematics and Dynamics (ME230) 2002
- Finite Element Analysis (ME478) 2001
- System Dynamics I and II (ME373 and ME374) 2000, 2001

NSF GK-12 Fellow, University of Washington Summer 01 – 2002

- Helped improve K-12 teachers' and students' mathematical understanding.
- Partnered with teachers to implement exemplary mathematics curricula that meet State of Washington and NCTM standards in K-12 classrooms.

AWARDS

Mechanical Engineering **Outstanding Undergraduate Educator**, CU Boulder 2021
Ebner Family **Faculty Fellowship**, CU Boulder 2019
NVIDIA **DLI University Ambassador**, Deep Learning Institute 2018
Mechanical Engineering **Outstanding Undergraduate Educator**, CU Boulder 2018
Certificate of Recognition for contributions to Massive Open Online Courses, University of Colorado President's Office 2014
Finalist for **Best Student Paper**, American Control Conference 2010
Lockheed-Martin **Outstanding Teaching Assistant**, UCLA 2008
Engineering Society of UCLA **Outstanding Teaching Assistant**, UCLA 2005
NSF **GK-12 Math Specialist Fellowship**, University of Washington 2002

FUNDED PROJECTS

1. Defense Advanced Research Projects Agency (DARPA), “Broadband Dual-Comb Spectrometry for Hazardous Material Detection,” $975,000 total award, Greg Rieker (PI), Jun Ye (Co-PI), Shalom Ruben (Co-PI). 2015-2018
2. National Science Foundation (NSF), “NSF CPS: In-Silico Functional Verification of Artificial Pancreas Controllers.”, Sriram Sankaranarayanan (Lead PI), Joint with David Bortz (CU Boulder), Shalom Ruben (CU Boulder), Fraser Cameron (RPI) and David Maahs (UC Denver Medical School), Funding Amount: $1M (CU Boulder share: $450,000). 2014-2017
3. Engineering Excellence Fund (EEF), “Portable, Low-Cost, Mechanical System For Hands-On Use in System Dynamics and Control Courses”, Shalom Ruben (PI). 2016
4. Engineering Excellence Fund (EEF), “Autopilot for the Space-Shuttle Docking Exhibit at the Denver Museum of Nature and Science”, Shalom Ruben (PI). 2014-2015
5. Engineering Excellence Fund (EEF), “Industrial Automation Laboratory for Education”, Shalom Ruben (PI). 2013-2014
6. Engineering Excellence Fund (EEF), “Fun Programmable Watch For Embedded System Education”, Shalom Ruben (PI). 2012-2013
7. Engineering Excellence Fund (EEF), “Control and Commutation of a Brushless Linear Motor with Nanometer Resolution”, Shalom Ruben (PI). 2011-2012

PUBLICATIONS

1. Daniel Y. Abramovitch, Sean Andersson, Kam K. Leang, William Nagel, and Shalom Ruben, ”A Tutorial on Real-Time Computing Issues for Control Systems,” *American Control Conference* (ACC), 2023, San Diego, CA
2. S. D. Ruben, ”The Times Tabulator (a Times Table Game using micro:bit)”, https://activities.sparkfuneducation.com/the-times-tabulator-a-times-table-game-using-microbit, 2019
3. Kevin C. Cossel, Eleanor M. Waxman, Fabrizio R. Giorgetta, Michael Cermak, Ian R. Coddington, Daniel Hesselius, Shalom Ruben, William C. Swann, Gar-Wing Truong, Gregory B. Rieker, and Nathan R. Newbury, ”Open-path dual-comb spectroscopy to an airborne retroreflector,” Optica 4, 724-728 (2017)
4. S. D. Ruben, ”Respect the Implementation: Using NI myRIO in Undergraduate Control Education,” *American Control Conference* (ACC), 2016, Boston, MA, pp. 7315-7320.
5. P. M. O. Gebraad, F. W. Teeuwisse, J. W. van Wingerden, P. A. Fleming, S. D. Ruben, J. R. Marden, and L. Y. Pao, ”Wind plant power optimization through yaw control using a parametric model for wake effects - a CFD simulation study,” *Journal of Wind Energy*, Volume 19, Issue 1, Pages 95-114, 2016.
6. S. D. Ruben, T-C. Tsao, R. Fesperman, O. Ozturk and R. R. Hocken, ”Modeling and Control of a Multi-Axis Nano-Precision Positioning System,” *Journal of Precision Engineering*, Submitted.
7. P. M. O. Gebraad, F. W. Teeuwisse, J. W. van Wingerden, P. A. Fleming, S. D. Ruben, J. R. Marden, and L. Y. Pao, ”A Data-Driven Model for Wind Plant Power Optimization by Yaw Control,” *American Control Conference*, 2014.
8. J. R. Marden, S. D. Ruben, and L. Y. Pao, ”A Model-Free Approach to Wind Farm Control Using Game Theoretic Methods,” *IEEE Transactions on Control Systems Technology*, Volume 21, Issue 4, pp 1207-1214, special issue “to tame the wind: advanced control applications in wind energy,”, 2013.

9. S. D. Ruben and T-C. Tsao, "Real-Time Optimal Commutation for Minimizing Thermally Induced Inaccuracy in Multi-Motor Driven Stages," *Automatica*, Volume 48, Issue 8, August 2012, Pages 1566-1574.
10. R. Fesperman, O. Ozturk, R. R. Hocken, S. D. Ruben, T-C. Tsao, J. Phipps, T. Lemmons, J. Brien and G. Caskey, "Multi-scale Alignment and Positioning System - MAPS," *Journal of Precision Engineering*, Volume 36, Issue 4, October 2012, Pages 517-537.
11. J. R. Marden, S. D. Ruben, and L. Y. Pao, "Surveying Game Theoretic Approaches for Wind Farm Optimization," Proceedings of *30th ASME Wind Symposium*, 2012.
12. S. D. Ruben, T-C. Tsao, T. Lemmons, G. Caskey, and R. R. Hocken, "Intrinsic Damping of Linear Halbach Brushless Motors," Proceedings of *ASPE 26rd Annual Meeting*, 2011.
13. S. D. Ruben and T-C. Tsao, "Optimal Commutation Laws by Real-Time Optimization for Multiple Motor Driven Systems," *American Control Conference*, 2010.; Finalist for "Best Student Paper"
14. S. D. Ruben, T-C. Tsao, R. R. Hocken, R. Fesperman, O. Ozturk, J. Brien and G. Caskey, "Mechatronics and Control of a Precision Motion Stage for Nano-Manufacturing," Proceedings of *Dynamic Systems and Control Conference*, 2009.
15. S. D. Ruben and T-C. Tsao, "Motion Control and Optimization for Nano Lithography," Proceedings of *ASPE 23rd Annual Meeting*, 2008.
16. S. D. Ruben and I. Y. Shen, "Evaluating Vibration Characteristics of a Disk Media Substrate," *Journal of Information Storage and Processing Systems*, 1999.

THESIS STUDENT PROJECTS

1. *Masters Thesis Student Advisor* 2018-2019
Matthew Hanley received an M.S. Degree in Mechanical Engineering and his thesis was entitled "Tools and Techniques for Improving Computational Efficiency on GPUs for Engineers". This wore provided the tools necessary for someone without an extensive background in computer science to write code that can be implemented on NVIDIA GPUs. These tools include: 1) fundamental concepts needed to understand the parallel programming model, 2) equations to guide programmers to make educated decisions when parallelizing programs, 3) suggestions on where programmers should focus attention to get the most benefit from the GPU, and 4) a discrete method to get a program from concept to running on a GPU. The goal is to empower professionals, students, and enthusiasts in the STEM community to both recognize when a program can be parallelized and to have the understanding of how to parallelize a program.

NON-THESIS STUDENT PROJECTS

1. *Undergraduate Independent Study Advisor* 2023
Branson Camp designed the fundamental building blocks of an Analog Synthesizer, which include the voltage-controlled-oscillator (VCO) and a two-pole voltage-controlled-filter (VCF). Branson needed to research all the different variations of these building blocks and also needed to learn the fundamentals of electronic components like diodes, transistors (both BJT and FET), and Op-Amps. He also conducted experiments to show how these components function which will lead into the second semester of this project which will be to build the prototype synthesizer.
2. *Undergraduate Independent Study Advisor* 2023
Andrew Carpender built, from scratch, a digital watch on a breadboard. This entailed learning how to program a mini 8-bit microprocessor (ATMEL ATTiny84)

using embedded C programming and interfacing with a 32 KHz quartz chrystal to measure time and 7-segment digits to display time. Andrew designed and 3D printed a case which included a small LIPO battery for power.

3. *Undergraduate Independent Study Advisor* 2023
   Martin Myszynski was tasked to explore, very deeply, a microcontroller (Arduino Due) from an embedded systems perspective so as to control an unstable inverted balance wheel. Martin was able to implement a realtime controller and access, via register manipulation, the analog and digital input and outputs to control the motor and read in the sensor feedback. This work will be used in future implementation of the technical elective “Industrial Automation”.
4. *Undergraduate Independent Study Advisor* 2022
   Hugh Scribner was tasked to design a new physical system that would be used to teach signals and systems in the System Dynamics (MCEN 4043) labratory portion of this course. The goal is to replace an all circuit system with a system that also includes a mechanical portion which is arguably more intuitive for mechanical engineering students. Hugh designed and build a motorized flywheel controls systems that used only analog components and no microcontrollers.
5. *Undergraduate Independent Study Advisor* 2022
   Bryce Kaese designed and fabricated the mechanical components of a autonomous graffiti robot. This project is essentially to build a CNC plotter that stands vertical instead of horizontal with a six foot by eight foot frame that draws using spray-paint instead of with a pen.
6. *Undergraduate Independent Study Advisor* 2021
   Wesley Schumacher designed, fabricated, and programmed a line-following robot. The goal was to design a ”high-speed” line-following robot that could compete in competitions and was motivated by videos of such competitions in Japan. Due to the high-performance nature of this robot, the design, and component choices were based on a dynamic model of the robot. Wesley was able to manufacture the robot and is going to continue the project to iterate his design after testing the current design.
7. *Undergraduate Independent Study Advisor* 2021
   Alec Ebner was tasked to design and implement an experimental procedure to attain the frequency-response-function (FRF) of headphones. The goal is to objectively compare various headphones, rather than subjectively through human listening. In addition, this is to be used in Signals and Systems courses to demonstrate the power of the FRF and to show the features, like bass-boost etc, for different headphones.
8. *Graduate Independent Study Advisor* 2021
   Tristan Schoeman was tasked to extend on Gabe Rodriguez’s and Matthew Ballinger’s work on Autonomous RC Car control by adding a trailer to the RC Car and driving the RC Car backwards with a Trailer. This entailed digging into a new firmware (ArduPilot instead of PX4) for the Pixhawk Autopilot and learning how to integrate an IMU, mounted on the trailer, and implement a Kalman Filter to estimate the angle of the trailer relative tot he RC Car.
9. *Graduate Independent Study Advisor* 2020
   Andrew Kuklinski was tasked to gain and understanding of vacuum-tube (aka valve) based circuits by designing and construct separate left and right channel dual stage RIAA preamplifiers, construct a low and high voltage power supply to provide power to the preamp in order to bias and heat the valves so they operate at the design operating point, design functional PCBs for each of the preamp circuits and power supply. Each stage of the design should be clearly

marked with silkscreen and arranged in a way to facilitate future learning and teaching.

10. *Graduate Independent Study Advisor* 2020
Gabriel Rodriguez was tasked to extend on Matthew Ballinger's work on Autonomous RC Car control by adding a trailer to the RC Car and driving the RC Car backwards with a Trailer. This entailed digging into the firmware of the Pixhawk Autopilot and learning how to integrate an IMU, mounted on the trailer, and implement a Kalman Filter to estimate the angle of the trailer relative tot he RC Car. Finally a preliminary autonomous reverse trailer assist control algorithm was simulated but was not implemented on the Pixhawk by the end of the semester.

11. *Graduate Independent Study Advisor* 2020
Joaquin Castillo, in collaborating with Prof. Joel Kralj in Biology, worked on automating the tracking and elimination of unwanted cells under a microscope. Using computer vision and mechatronics algorithms, Joaquin wrote Labview code that integrated with the microscope optics, an X-Y stage under the microscope for course motion, and an two-stage steering mirror, and laser light. Although the original target was lofty for a one semester research project, Joaquin manager was able to set up the software framework to integrated all the hardware and left it in a great place for the next researcher to take the next steps.

12. *Undergraduate Independent Study Advisor* 2020
Emily Page designed, fabricated, and programmed a fully functional "Clock Clock", a time display device where the time is written out (in digital format) using the hour and minute hands of 24 analog clocks. Each clock was custom fabricated, with two motors driving the each hand of the clock into their respective position. Aside from time, the clock could read out the date or the temperature of the ambient room, and even produce some visual effects such as swirls or patterns.

13. *Undergraduate Independent Study Advisor* 2020
Grant Stewart was tasked to design a passive isolation system to mitigate transient vibrational noise in a vinyl record player system. The first semester, a passive vibration isolation table, acting as a low-pass-filter, was designed based on magnetic repulsion rather than a mechanical spring. In the second semester, Grant designed and manufactured an active vibration isolation table based on electromagnetic actuation and hall-effect sensors as feedback to Arduino microcontroller.

14. *Graduate Independent Study Advisor* 2019
Paul Salame on designing and building a novel Double Pendulum system for implementing, testing, and comparing state-estimation (or sensor-fusion) algorithms. First, the hardware selection (mechanical system, sensors, and microcontroller) was manufacturing was conducted. Next, theoretical equations of motion and state space models for the system were derived. Finally, the design and implementation of various state estimation techniques. Some of the state estimation techniques include the Linearized Kalman Filter, Extended Kalman Filter, Complementary Filter, the Mahony Filter, and an IMU-based Kalman Filter.

15. *Graduate Independent Study Advisor* 2019
Matthew Ballinger on using RC (remote control) cars (or rovers) as platforms for for learning to design, implement, and test control algorithms for autonomous vehicles. He integrated an off-the-shelf autopilot for RC Planes (or drones) with an off-the-shelf RC Car, but had to explore the structure of the firmware on the autopilot and figure out how to "hack" the code so that we can incorporate our own user-written firmware over shipped code.

16. *Undergraduate Independent Study Advisor* 2019
Riley Kenyon was tasked to build off of a previous controls project to optimize the automation of a phone game utilizing a GPU, rather than a CPU. In the original construction of the automation unit, a RaspberryPi 3B+ was used as the CPU device to control the project. In order to do more complex manipulation of pixel values and advanced image processing techniques, a more capable device was employed: the Nvidia Jetson TX2 and later the Jetson Nano embedded GPUs.
17. *Undergraduate Independent Study Advisor* 2019
David Gerstle utilized a "Fidget Car", which is an open sourced car with a distance sensor and a built-in analog controller to get hands-on experience on system identification, controller design, and controller implementation. David also designed an inverted pendulum mount and modified the fidget car to allow control of an inverted pendulum and then implemented a stabilizing controller.
18. *Undergraduate Independent Study Advisor* 2019
Chet Roe on designing and building a speaker, including building the enclosure, speccing out the woofer and tweeter drivers, and most importantly designing and building the crossover filters (low-pass and high-pass filters) from scratch so as to get the flattest frequency response function.
19. *Undergraduate Independent Study Advisor* 2019
Matt Pipan on designing and building a speaker, including building the enclosure, speccing out the woofer and tweeter drivers, and most importantly designing and building the crossover filters (low-pass and high-pass filters) from scratch so as to get the flattest frequency response function.
20. *Undergraduate Independent Study Advisor* 2018
Jordan Shimonek took over where Andrew Bradford left off, on designing and building a guitar auto-tuning control system. Jordan designed, printed, and build, a PCB version of the auto-tuning controller bread-board prototype in the form of an Arduino daughter-board or shield.
21. *Undergraduate Independent Study Advisor* 2018
Darwin Wood on designing and building a low-cost Inverted Pendulum demonstration module for use in System Dynamics and Feedback Control courses. This project entails the specify of sensors, actuators, power, and chassis, and then building integrating and writing control algorithms on a microcontroller to stabilize the system.
22. *Undergraduate Independent Study Advisor* 2018
Roy Powell on designed and building a vacuum tube (aka valve) based filtering amplifier to demonstrate analog frequency response function and explore the history of vacuum tubes related to the now more common operation-amplifier (OpAmp).
23. *Undergraduate Independent Study Advisor* 2018
Mack Tang on designing and a building a robotic system that uses Visual Servoing. Visual Servoing is a controlled system where the feedback information is attained by using image processing and computer vision techniques on a camera images to estimate the system output.
24. *Undergraduate Independent Study Advisor* 2018
Andrew Bradford on designing and building a guitar auto-tuning control system. This system entails the reading the signal of guitar pickup into a micro-controller and, using signal processing techniques, deducing the fundamental frequency which will inform the control system to increase or decrease the tension on the string via a motor.

25. *Undergraduate Independent Study Advisor* 2018
Matthew Hanley on learning how to program an NVIDIA Graphical-Processing-Unit (GPU) and then implementing computer vision algorithms to gain higher bandwidth compared to running the algorithms on a CPU.

26. *Graduate Independent Study Advisor* 2017-2018
Issac Ross to continue the project on automating the Denver Museum of Nature and Science (DMNS) Space Craft Docking Exhibit by implementing computer vision based tracking on the raspberry pi.

27. *Undergraduate Independent Study Advisor* 2017
Ryan Mettler on designing a low-cost 3D printed camera gimbal and implementing computer vision algorithms in preparation for a new Introduction to Computer Vision course.

28. *Undergraduate Independent Study Advisor* 2017
Jeff Lim on designing and implementing a floppy-disk-drive orchestra using which played midi music files via the mechanical motion of the floppy drives which produced sound.

29. *Graduate Independent Study Advisor* 2017
Zach Ott coded a low-cost quadcopter with his own stabilizing controller to demonstrate that this hardware could be used as a hands-on experiment in future control courses.

30. *Undergraduate Independent Study Advisor* 2016-17
Carmelo Gonzales on understanding the code on a popular open-source CNC router controller, so that we may adapt the control and trajectory algorithms to increase performance and minimize vibrations commonly occurring in parts with sharp edges.

31. *Undergraduate Independent Study Advisor* 2016
Philip Nystrom on adapting a mechanical systems lab on a PCB, developed at MIT, to be used in ME's System Dynamics course.

32. *Graduate Independent Study Advisor* 2016
Chinmay Morankar on temperature and flow control for a hybrid electric solar hot water heating system.

33. *Undergraduate Independent Study Advisor* 2015 - 2016
Kyle Samples on automating the Denver Museum of Nature and Science (DMNS) Space Craft Docking Exhibit using a Windows Kinect camera.

34. *Undergraduate Independent Study Advisor* 2016
Philip Nystrom on designing components of an analog computer to be used in undergraduate control course for analog simulation of systems.

35. *Graduate Design Group Advisor* 2015 - 2016
On ground to unmanned autonomous system (UAS) laser link for long range detection of hazardous gasses for the National Institute of Standards and Technology (NIST).

36. *Undergraduate Independent Study Advisor* 2015
Andrew Atkinson on optimizing Ultra Mileage Vehicle boosting strategy for a known track profile.

37. *Undergraduate Independent Study Advisor* 2014
Tim Cureton on Enhancing Undergraduate PID line-following lab, in System Dynamics course, by closing loop around wheel speed.

38. *Undergraduate Independent Study Advisor* 2014
Davis Haberkorn on designing a gear steering mechanism for a bicycle in hopes of reducing steering output angle, vs. input steer angle, for special needs user.

39. *Graduate Independent Study Advisor* 2013
Michael Tanksalvala on implementing an algorithm, via FPGA, to read in an analog SIN/COS encoder and convert to position and use for control of a nanometer positioning stage.