WORKSHOP PROPOSAL

Proposed Workshop Title:

Methods of Easily Verifiable Control Design

to be Organized at:

American Control Conference (ACC)
July 6–8, 2016
Boston, MA, USA

Organizers

Dr. Mahdi Shahbakhti, Michigan Technological University (PIN: 57350)
Dr. Karl Hedrick, University of California - Berkeley (PIN: 2520)
Dr. Kenneth Butts, Toyota Motor Company (PIN: 837)

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Format

1/2 day workshop

Rationale

Verification and Validation (V&V) are essential stages in the design cycle of controllers. V&V for complex dynamic systems is costly and time consuming. For instance, the 2006 Lexus LS460 had more than 100 electronic control units (ECUs) with total program size of seven million lines [1]. Using the current technology, the V&V process and calibration of ECUs for a modern vehicle take approximately two man-years, and it costs several million dollars. Reducing cost and time of V&V is a major challenge for all complex control systems. A large number of errors detected during independent V&V are introduced during the initial stages of controller development. V&V *would cost 10 times less* if those errors could be identified and fixed during the early stages of controller software design [2]. Design and implementation of controllers involves the interaction and coordination of three disciplines: control engineering, software engineering, and electronic hardware engineering. A critical gap occurs when uncertainty in controller software/hardware implementation is not considered as part of the controller design.

This workshop presents new theoretical and experimental approaches for design of easily verifiable controllers that minimize V&V iterations for complex industrial control systems. The workshop materials range from introductory to state-of-the art research using our previous work [3-15] and recent results [16-17] from our NSF project on the topic of easily verifiable controller design. Our new results [16-17] show that the tracking performance of controllers under implementation imprecision can be improved by 40-90% using our proposed control design techniques. In this workshop, we will (i) provide an overview for major sources of controller implementation imprecisions, (ii) present techniques to model/simulate uncertainties arising from controller implementation, (iii) introduce new approaches to make a controller design robust to implementation uncertainties that originate from sampling, quantization, and processor computation limit, (iv) describe techniques to assess controllers' robustness in software-in-the-loop (SIL), processor-in-the-loop (PIL), and hardware-in-the-loop (HIL) test setups, and (v) have in-workshop real-time demonstration of the introduced techniques on an experimental test bench designed for control of engine throttle body (i.e., DC brush motor).

Presenters

- Dr. J. Karl Hedrick, James Marshall Wells Academic Chair, Professor of Mechanical Engineering, University of California, Berkeley. Dr. Hedrick's expertise includes theory of easily verifiable controller design, nonlinear estimation and controls ranging from describing functions to sliding mode observers, sliding mode control and dynamic surface control.
- Dr. Mahdi Shahbakhti, Director of Energy Mechatronics Laboratory, Assistant Professor of Mechanical Engineering, Michigan Technological University. Dr. Shahbakhti's expertise includes embedded controller hardware/software, modeling uncertainties involved in the implementation of controllers, and automotive controls.
- Dr. Selina Pan, Postdoctoral Researcher, Mechanical Engineering, Stanford University. Dr. Pan's research is in autonomous vehicles, particularly in ethics, driver adaptation, and integrated path planning and tracking. Her Ph.D. research was on the design of control methods to mitigate uncertainty in nonlinear systems, including discrete-time and adaptive frameworks.
- Mr. Andreas Hansen, Graduate Research Assistant, University of California Berkeley, Professor Karl Hedrick's Vehicle Dynamics Laboratory. Mr. Hansen's PhD thesis research focuses on theory and implementation of receding horizon sliding control (RHSC) for linear and nonlinear systems. His newly developed RHSC techniques have the capability for reducing computation cost of commonly used model predictive controllers while meeting control targets and satisfy operational constraints.
- Mr. MohammadReza Amini, Graduate Research Assistant, Michigan Technological University, Professor Mahdi Shahbakhti's Energy Mechatronics Laboratory. Mr. Amini's PhD thesis has centered on modeling uncertainty/imprecision from controller implementation and theory of easily verifiable controller design. As part of his PhD, he has developed techniques of uncertainty-adaptive discrete sliding controllers that are robust to implementation imprecisions.

Schedule

10 min – Workshop overview (Dr. Shahbakhti)

15 min – Introduction to sources of controller implementation impressions (Dr. Hedrick)

20 min – Techniques to simulate and assess controller implementation imprecisions (Dr. Shahbakhti)

30 min – Easily verifiable controller design (EVCD)-I: Discrete sliding control and incorporating uncertainty bounds (Mr. Hansen)

15 min – Break

35 min EVCD-II: robust control with on-line uncertainty prediction* (Mr. Amini)

40 min – EVCD-III: Adaptive discrete sliding control* (Dr. Pan, Mr. Amini)

15 min – Break

40 min – EVCD-IV: Receding horizon sliding control* (Mr. Hansen)

15 min – Outlook (open issues and future direction) and Discussion (Dr. Hedrick)

* *includes demonstration of automotive case studies to preview the significance of the methods.*

Audience

We hope to reach (i) control practitioners interested in making their controller designs easily verifiable and reducing V&V cost and time, (ii) control students and researchers who are interested in model-based controller design and verification, and (iii) control practitioners interested in improving their verification cycle of controllers by leveraging new techniques of early model-based verification. Our goal is to promote new techniques of easily verifiable controller designs to benefit the control community and gather valuable feedback on our approach.

References

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[4] M. Amini, M. Shahbakhti, A. Ghaffari, " A Novel Singular Perturbation Technique for Model-Based Control of Cold Start Hydrocarbon Emission ", *SAE Int. J. Engines* , Vol. 7, Issue 3, 2014.

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[6] S. Pan, K. Edelberg, and J. K. Hedrick, Discrete Adaptive Sliding Mode Control of Automotive Powertrains, 2014 American Control Conference.

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[14] A. Hansen, J. K. Hedrick, " Receding Horizon Sliding Control for Linear and Nonlinear Systems ", 2015 American Control Conference, 6 pages, July 1-3, 2015, Chicago, USA.

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