Model Predictive Control Workshop

James B. Rawlings
Department of Chemical and Biological Engineering
University of Wisconsin
Madison, Wisconsin

Thomas A. Badgwell
ExxonMobil Research & Engineering
Clinton, NJ

October 17, 2015

Rationale

Model predictive control (MPC) has become the most popular advanced control method in use today. Its main attractive features are (i) optimization of a model forecast over the available actuators (ii) estimation of the state of the system and disturbances from the process measurements, (iii) accounting for the process and actuator constraints, and (iv) accounting for full multivariable interactions. After its introduction in the process industries in the 1970s, MPC has today become a pervasive control technology in many industries, and is now being increasingly deployed for optimization of high-level functions such as minimizing energy consumption and maximizing product quality.

This workshop is intended to introduce graduate students and practitioners to the theory and design of MPC systems.

The two days of lectures will cover the following topics.

1. Model predictive control: regulation problem, dynamic programming, linear quadratic regulator, constraints, infinite horizon, LQR, constrained regulation.

2. State estimation: least-squares estimator, Kalman filter, observability and convergence.

3. Putting regulation and estimation together, industrial practice, disturbance models, and offset.

4. Nonlinear MPC. introduction, stability, Lyapunov function theory, disturbances and robust stability, nominal stability, suboptimal MPC, inherent robustness of optimal and suboptimal MPC, some examples.

Preprint submitted to 2016 American Control Conference.
Received October 24, 2015.

5. Nonlinear moving horizon state estimation. full state estimation, moving horizon estimation with zero prior weighting, nonzero prior weighting, constrained estimation.

6. Economic MPC. problem formulation and properties, periodic constraints. open research issues.

7. Other topics: Suboptimal MPC, MPC with discrete actuators.

Tentative schedule. The tentative schedule for the two-day workshop is attached.

Relationship to other MPC Workshop. Another MPC Workshop proposal that we are aware of is "Model predictive control under uncertainty: Theory, Computations and Applications," by Sasa V. Rakovic, William S. Levine, Behcet Acikmese and Ilya V. Kolmanovsky. We have been in communication with these authors and feel that the topics are quite different and overlap is not an issue. If both proposals are approved, we recommend in the workshop advertising that the workshop proposed here be advertised for those wanting an introduction to MPC, and the MPC under uncertainty workshop be advertised for those already with research experience in the MPC field.

Our proposed workshop is similar in scope to the two-day workshop that we presented at the 2015 ACC meeting in Chicago. At that workshop we hit our limit of 25 attendees, and had to decline attendance for about 10 more people who wanted to sign up for the workshop at the meeting registration.

About the presenters

James B. Rawlings. He received the B.S. from the University of Texas in and the Ph.D. from the University of Wisconsin, both in Chemical Engineering. He spent one year at the University of Stuttgart as a NATO postdoctoral fellow and then joined the faculty at the University of Texas. He moved to the University of Wisconsin in 1995 and is currently the Paul A. Elfers Professor and W. Harmon Ray Professor of Chemical and Biological Engineering, and the co-director of the Texas-Wisconsin-California Control Consortium (TWCCC).

Professor Rawlings's research interests are in the areas of chemical process modeling, monitoring and control, nonlinear model predictive control, moving horizon state estimation, and molecular-scale chemical reaction engineering. He has written numerous research articles and coauthored three textbooks: "Modeling and Analysis Principles for Chemical and Biological Engineers" (2013) with Mike Graham, "Model Predictive Control: Theory and Design" (2009), with David Mayne, and "Chemical Reactor Analysis and Design Fundamentals," 2nd ed. (2012), with John Ekerdt.

In recognition of his research and teaching, Professor Rawlings has received several awards including:

Preprint submitted to 2016 American Control Conference.
Received October 24, 2015.

- "Doctor technices honoris causa" from the Danish Technical University;
- Inaugural High Impact Paper Award from the International Federation of Automatic Control;
- Ragazzini Education Award from the American Automatic Control Council;
- Computing in Chemical Engineering Award and Excellence in Process Development Award from the AICHE;
- Chancellor's Distinguished Teaching Award, WARF Named Professorship, and the Byron Bird Award for Excellence in a Research Publication, from the University of Wisconsin;

He is a fellow of IEEE and AIChE.

Thomas A. (Tom) Badgwell. He is an Advanced Research Associate in the Data Analytics & Optimization Section, Corporate Strategic Research, at the ExxonMobil Research & Engineering Company in Clinton, NJ. He received a B.S. degree in Chemical Engineering from Rice University and M.S. and Ph.D. degrees from the University of Texas at Austin. Tom's career has focused on research, development, and application of MPC technology, with past positions at Setpoint, Fisher/Rosemount, Rice University, and Aspen Technology. He received the 2005 Control Engineering Practice Best Paper Prize for his MPC survey article with Professor Joe Qin (2003). He received the 2013 AIChE Computing and Systems Technology Division Computing Practice Award for his contributions in the theory and practice of MPC applied to the process industries. He is a fellow of AIChE, an Associate Editor for the Journal of Process Control, and serves as a Trustee of the Computer Aids in Chemical Engineering (CACHE) Corporation.

References

S. J. Qin and T. A. Badgwell. A survey of industrial model predictive control technology. *Control Eng. Pract.*, 11(7):733–764, 2003.

J. B. Rawlings and D. Q. Mayne. *Model Predictive Control: Theory and Design*. Nob Hill Publishing, Madison, WI, 2009. 576 pages, ISBN 978-0-9759377-0-9.

Preprint submitted to 2016 American Control Conference.
Received October 24, 2015.

Schedule: Model Predictive Control Workshop

James B. Rawlings
Department of Chemical and Biological Engineering
University of Wisconsin-Madison

Thomas A. Badgwell
ExxonMobil Research & Engineering
Clinton, NJ

July 4–5, 2016

American Control Conference, Boston, MA

Session 1: Monday 8:30AM to 12:00PM

1. Introductions
2. Introductory review: linear regulation and state estimation
3. Break and software installation
4. Tracking, disturbances, and zero offset (part 1)

Lunch: Monday 12:00PM to 1:00PM

Session 2: Monday 1:00PM to 4PM

1. Tracking, disturbances, and zero offset (part 2)
2. Nonlinear MPC – Regulation (part 1)

Session 3: Tuesday 8:00AM to 12:00PM

1. Nonlinear MPC – Regulation (part 2)
2. Nonlinear moving horizon estimation

Lunch: Tuesday 12:00PM to 1:00PM

Session 4: Tuesday 1:00PM to 5PM

1. Economic MPC
2. Other Topics: Suboptimal MPC and Hybrid MPC
3. Summary

Preprint submitted to 2016 American Control Conference.
Received October 24, 2015.