Gain Scheduled Model Predictive Control: Design and Implementation Using MATLAB®

Speakers: Liuping Wang, RMIT University and NICTA, Victoria Research Laboratory, Australia
Craig Buhr, MathWorks

This short-course is partially sponsored by MathWorks

Course Outline

Model Predictive Control (MPC) has a long history in the field of control engineering. It is one of the few areas that has received on-going interest from researchers in both the industrial and academic communities. Three major aspects of model predictive control make the design methodology attractive to both engineers and academics. The first aspect is the design formulation, which uses a completely multivariable system framework where the performance parameters of the multivariable control system are related to the engineering aspects of the system; hence, they can be understood and 'tuned' by engineers. The second aspect is the ability of method to handle both 'soft' constraints and hard constraints in a multivariable control framework. This is particularly attractive to industry where tight profit margins and limits on the process operation are inevitably present. The third aspect is the ability to perform process on-line optimization.

The model predictive control systems are designed using linear models unless a nonlinear model is explicitly stated. Nonlinear model predictive control is conceptually similar to its linear counterpart except that nonlinear models are deployed for the prediction and optimization. However, because of its computational intensity and complexity, the nonlinear predictive control systems are not as widely applied as its linear counterpart. Instead, the gain scheduled control system techniques have found success in the area of predictive control of nonlinear plants. This one-day short-course will show the four steps involved in the design of a gain scheduled predictive controller: (i) linearization of a nonlinear plant model according to operating conditions; (ii) the design of linear predictive controllers using the family of linear models; (iii) gain scheduled predictive control law that will optimize a multiple model objective function with constraints, which will also ensure smooth transitions (i.e. bumpless transfer) between the predictive controllers; (iv) simulation and experimental validation of the gain scheduled predictive control system with constraints using MATLAB® and Simulink® as a platform. The core material of this course, based on the book entitled ‘Model Predictive Control System Design and Implementation using MATLAB’ by the first speaker, is suitable for engineers, students and researchers who wish to gain basic knowledge about gain scheduled model predictive control of nonlinear plant, as well as understand how to perform real time simulation and implementation using MATLAB and Simulink tools.

Course Schedule

9:00-10:30: Introduction to Model Predictive Control

Course overview, design formulation using velocity form model, receding horizon control, state estimation.

10:30-10:45 Coffee Break

10: 45-11:45 Design of Predictive Controllers using a Family of Linear Models

Linearization of nonlinear plants based on physical models, plant operating conditions, small signal models, controller performance specifications, observer performance specification.

11: 45-12:45 Plant Modelling from SolidWorks and Simulink

Craig from MathWorks will show how to create a plant model by automatically importing CAD assembly from SolidWorks to Simulink, followed by explaining how to model and calibrate DC motor actuators and how to combine electrical and mechanical components into the overall plant model.

12:45 – 1:45 Lunch Break

Lunch is sponsored by MathWorks.

13:30-14:30 Gain Scheduled Model Predictive Controllers

Multiple model objective function, interpretation of the linear predictive controllers, smooth transition between the predictive controllers.

14:30-15:30 Constrained Gain Scheduled Model Predictive Controllers

Linear approximation of nonlinear constraints, formulation of linear inequality constraints, active constraints, inactive constraints, Hildreth quadratic programming algorithm.

15:30-16:00 Coffee Break

16:00-17:00 Real Time Simulation and Implementation of Model Predictive Control

Craig will explain how you can design a model predictive controller for a robot arm. Craig will compare the performance of the MPC controller with a multi-loop PID controller and will show bumpless transfer from one controller to another. Finally, Craig will show how you can automatically generate C code for real-time controller testing on a real-time target machine. The demonstration will end with a real-time control of the robot arm hardware using the model predictive controller.

About the Speakers

Professor Liuping Wang received her Ph.D degree in 1989 from the Department of Automatic Control and Systems Engineering, University of Sheffield, UK. Upon completion of her PhD degree, she worked in the Department of Chemical Engineering at the University of Toronto, Canada for eight years in the field of process control. From 1998 to 2002, she worked in the Center for Integrated Dynamics and Control, University of Newcastle, Australia. In February 2002, she joined the School of Electrical and Computer Engineering, RMIT University, Australia where she is a Professor of Control Engineering. She has authored and co-authored more than 150 scientific papers in the field of system identification, PID control, adaptive control, model predictive control, electrical drive control and control technology application to industrial processes. She co-authored a book with Professor Will Cluett entitled *From Process Data to Process Control- Ideas for Process Identification and PID control* (Taylor and Francis, 2000). She co-edited two books with Professor Hugues Garnier entitled ‘ *Continuous time model identification from sampled data*’ (Springer-Verlag, 2008) and ‘System identification, environmental modelling and control’ (Springer-Verlag, 2011) . Her book entitled ‘ *Model Predictive Control Design and Implementation using MATLAB®’* was published by Springer-Verlag in 2009, and the second edition of this book is currently under preparation. She is the leading author of the book entilted ‘PID and predictive control of electrical drives and power converters using *using MATLAB®*’ that will be published by Wiley in 2013. Dr Liuping Wang has successfully applied the predictive control technologies to food extruders, automotive brake-by-wire systems, magnetic bearing systems, electrical drives and power converters. Dr Liuping Wang is an associate editor of International Journal of Control and Journal of Process Control, and a Fellow of Institute of Engineers Australia.

Craig Buhr graduated from the School of Mechanical Engineering at Purdue University in 1993. He later received his M.S. and Ph.D. degrees from the School of Mechanical Engineering at Purdue University in 1996 and 2003, respectively. His research interests include dynamic system modeling and identification, linear systems and control theory. He joined the MathWorks as a Senior Developer for the Control System Toolbox in 2003 developing software tools to facilitate the design and analysis of control systems. He is currently the Senior Team Lead of the Control Design group.