Model Predictive Control in Cascade System Architecture: Design, Implementation and Applications Using MATLAB®

Pre-conference workshop in 55th of Conference on Decision and Control, Las Vegas, USA, 11th of December, 2016

Speakers: Professor Liuping Wang, RMIT University, Australia

Dr Craig Buhr, MathWorks

This workshop is partially sponsored by MathWorks

Workshop 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.

In many applications, MPC is designed in a cascade system architecture where there is a primary control objective combined with a secondary control objective. The advantages of MPC in a cascade structure include simplification of the design, effectively handling nonlinearities and parameter variations through feedback control, reducing computational costs using dual sampling rate, imposing operational constraints on the secondary process variables, and improving characteristics of disturbance rejection.

Using real-world applications and simulation examples, this one-day workshop will show the four steps involved in the design of model predictive control in cascade control system architecture: (i) selection of primary and secondary variables and configurations of cascade model predictive control; (ii) design of inner-loop and outer-loop predictive control systems; (iii) the design of constrained predictive control systems in cascade structure using quadratic programming algorithms; (iv) simulation and experimental validation of the cascade predictive control system with constraints using MATLAB® and Simulink® as a platform.

The core material of this workshop, based on the books entitled 'Model Predictive Control System Design and Implementation using MATLAB' (Springer, 2009) and 'PID and Predictive Control of Electrical Drives and Power Converters using MATLAB and Simulink' (Wiley-IEEE PRESS, 2015) by the first speaker, is suitable for engineers, students and researchers who wish to gain basic knowledge about predictive control as well as understand how to perform real time simulation and implementation using MATLAB and Simulink tools.

The lecture slides and MATLAB/Simulink programs used in the examples will be made available to the participants, and they are welcome to bring their applications and problems to the workshop for discussions.

Workshop Schedule

9:00-10:30: Introduction to Cascade Control System Architecture

Primary control objectives, secondary control objectives, examples of cascade control systems: reference following and disturbance rejection; electrical drives, unmanned aerial vehicles.

10:30-10:45 Coffee Break

10: 45-11:45 Design of Cascade Model Predictive Control Systems

Design MPC for secondary process variables; design of MPC to achieve primary control objectives; closed-loop stability of cascade model predictive control; tuning of cascade MPC using exponential data weighting and prescribed degree of stability.

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

Dr 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 – 13:45 Lunch Break

Lunch is sponsored by MathWorks.

13:45-14:45 Constrained Cascade Model Predictive Controllers

Formulation of linear inequality constraints for the manipulated variables and the secondary process variables, active constraints, inactive constraints, Hildreth quadratic programming algorithm.

14:45-15:45 Finite Control Set- Model Predictive Control (FCS-MPC)

Successful applications of cascade control in electrical drives and power converters, FCS-MPC in electrical drives and power convert control.

15:45-16:00 Coffee Break

16:00-17:00 Cascade control for sensor bias compensation

Angular position control of electrical drives, current sensor bias compensation through cascade control, simulation results and experimental results.

About the Speaker

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 180 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 lead author of the book entilted *‘PID and Predictive Control of Electrical Drives and Power Converters using MATLAB®’* published by Wiley-IEEE in 2015. 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, Journal of Process Control, IEEE Transactions on Control System Technologies and a Fellow of Institution of Engineers Australia.

Dr 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.