Discrete SISO Controller Design: The Time Series Approach

Presenter: Dr. Ky M. Vu (AuLac Technologies Inc.)

1 Workshop Summary

The purpose of a control professional to take a course in control theory is to be able to design a controller for his use. There are different controllers for different purposes, and there are different design methodologies for them. Since the control is usually through time, analysis and design should have time as the pivotal variable. The control strategy to minimize the variance of the controlled variable ARMA time series with a constraint on the variance of the control variable, of a discrete feedback control system, gives a linear quadratic Gaussian control algorithm. For H-infinity control, the least sensitive controller gives the controlled variable a noninvertible ARMA time series: a time series with a flat spectrum. Model predictive control requires prediction of a future value of the controlled variable ARMA time series. The ARIMA time series holds an important position in stochastic control theory. A fundamental knowledge of the ARIMA time series and its analysis is, therefore, an essential knowledge for a control professional, engineer or instructor, to have for his or her control design.

This full-day workshop presents the result of 5-year research in time series analysis and stochastic control theory of AuLac Technologies Inc., www.aulactechnologies.com. After attending the workshop, an attendee will have the knowledge to analyze and design discrete controllers and digital filters for linear systems with formulas of moments and spectra. This knowledge will be supplemented with the knowledge of periodic and aperiodic time series, prediction and (Kalman) filtering as well as fundamental statistics. An attendee will know the industrial Dahlin, Vogel-Edgar, IMC and also the PID deterministic tracking controllers. For the stochastic regulating controllers, the workshop will discuss the one-step, N-step and infinite-step optimal controllers, model predictive as well as the H-infinity controllers.

The lecture notes will be extracted from the two textbooks: "The ARIMA and VARIMA Time Series: Their Modelings, Analyses and Applications" (ISBN 978-0-9783996-1-0) and "Optimal Discrete Control Theory: The Rational Function Structure Model" (ISBN 978-0-9783996-0-3), which come with the workshop. Demonstrations will be running MATLAB m.files. Each attendee should bring with him or her a notebook (laptop) with MATLAB software, or its clone like OCTAVE, installled on it for the demonstrations.

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2 Workshop Schedule

1. Morning session (8:00-12:00): Time series literature.

    - Basic background (60 min.).
        - The random variable, probability and statistics.
        - The expectation operator, moments and cumulants.
        - The discrete time series: periodic, aperiodic and ARIMA.
        - The model and modeling of an ARIMA/VARIMA time series.
    - Break (10 min.).
    - Analyses: Moments and spectra (80 min.).
        - The Autocovariance (crosscovariance) generating function and the autocovariances (crosscovariances).
        - The Autospectrum and the Cross-spectra.
    - Break (10 min.).
    - Applications: Forecast, prediction, controller design and digital filter spectra (80 min.).
        - Forecasts: Forecasts of an ARMA and a VARMA Time Series.
        - Prediction, filtering and the Kalman filters.
        - Stochastic Control Theory: The Box-Jenkins model and its controllers.
        - Digital Filter: Low-pass, high-pass, band-pass and all-pass filters.

2. Lunch break (60 min.).

3. Afternoon session (13:00-17:00): Discrete SISO controllers design.

    - Discrete linear control systems and time series (30 min.).
        - Time series models and controller types.
        - Deterministic tracking control systems.
        - Stochastic regulating control systems.
    - Break (10 min.).
    - Designing deterministic tracking controllers (60 min.).
        - The minimal prototype PID and the dead-beat controllers.
        - The Dahlin, Vogel-Edgar and IMC controllers.
        - The setpoint-model tracking controllers: 1-DOF and 2.5 DOF controllers.
    - Break (10 min.).

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- Designing linear quadratic stochastic controllers (60 min.).
  - The minimum variance controller.
  - The one-step optimal controller.
  - The N-step optimal controllers.
  - The infinite-step optimal controller.
- Break (10 min.).
- Designing H-infinity controllers (60 min.).
  - Signal and system norms.
  - The sensitivity functions.
  - The small gain theorem.
  - The least sensitivity controller.

3 Attendance

Who should attend? The following professionals should attend:

- Control, process control engineers: students as well as young instructors who want to consolidate their knowledge in this area.
- Digital signal processing engineers (for digital filter design).
- Time series analysts.

Estimated number of attendees: Twelve.

4 Biography of Presenter

Dr. Ky M. Vu was born in the kingdom AuLac (Vietnam) and educated in Canada. He got his B.A.Sc. at the University of Ottawa, his M.Eng. at McMaster University and his PhD. at the University of British Columbia. His research interests are in the theories of control, matrix and statistics. He has written numerous papers published in IEE Proceedings Control Theory and Applications, International Journal of Control, International Journal of System Sciences, Applied Mathematics and Computation and many control conference proceedings. He is a regularly invited paper reviewer for the Canadian IASTED Control and Applications conferences and the British IET Journal in control. He also has published two textbooks "Optimal Discrete Control Theory: The Rational Function Structure Model" (ISBN 978-0-9783996-0-3) and "The ARIMA and VARIMA Time Series: Their Modelings, Analyses and Applications" (ISBN 978-0-9783996-1-0).

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