Tutorial on

"State of the Art Computational Methods and Software for Control Systems" at the 5th Asian Control Conference, July 20, 2004, Grand Hyatt - Melbourne, Australia.

Lecturers:

1. **Biswa Datta**, *IEEE Fellow and Presidential Research Professor*, Northern Illinois University, DeKalb, Illinois, USA.
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2. **Other(s): TBA**.

Purpose: This one-day short course is designed to give a complete overview of of the state-of-the-art computational methods and the associated software for control systems design and analysis.

Importance of The Course: During the last two decades, numerically viable algorithms have been developed for most of the important tasks arising in control systems design and analysis. Softwares based on these methods have been developed and are still being built. Unfortunately, these techniques and the softwares do not seem to be widely known and/or are not being widely used by a broad group of control theorists and practicing engineers.
The primary reason for this appears to be that an understanding, efficient implementations, and making appropriate modifications of these methods as needed for some applications of special interests, require an interdisciplinary knowledge and expertise of scientific computing, control theory, and computer science; and such a combined expertise is hard to acquire without spending a great deal of time, and taking many diversified courses in different disciplines. What is needed, therefore, a self-sufficient course that can explain the the computational algorithms and software in a *rather elementary and user-friendly way without going into the depth of the associated numerical linear algebra techniques and relevant mathematical theory.* The proposed course aspires to do that. The lectures will be organized to clearly explain the algorithms in a manner that is suitable for easy implementations on computers, the important aspects of implementations will be clearly discussed, a clear and concise comparative study of one algorithms over the others for a given problem will be presented and recommendations, based on that study, will be made for the practicing engineers. *Mathematical and computational jargon that seem to be distractive for most engineers to learn these techniques will be avoided.* The minimal amount of numerical linear algebra background that are absolutely essential to understand the material will be presented in the course itself in a conceptual way, but giving the details of software and implementational issues.

Potential Benefits and Impact of the Workshop In recent years, there have been a surge of applications of control techniques in many important areas of science and engineering, including *Aerospace, Automotive, Medicines, Biology, Power Systems, Structural Dynamics, Manufacturing Engineering, and others*. For successful applications of these techniques with a view to solving practical-life problems, it is crucial that the control techniques needed by these applications are properly implemented using numerically robust computational methods and software.
The participants of this workshop will be exposed to the essential state-of-the-art useful computational techniques and software for control systems design and analysis, which can be used and further developed (as needed) in confidence in future research, teaching, and work on practical applications. The workshop will also provide motivation and practical guidance to the instructors teaching linear systems theory courses to include some state-of-the-art numerical techniques and software in their exiisting courses and/or design a exclusive graduate level course in this area.

Topics: All fundamental topics will be covered. These include:

- Modeling
- System Responses
- Numerical tests for Controllability, Observability and Distance to Uncontrollability
- Stability, Robust Stability and Distance to Instability
- Numerical Solutions and Conditioning of Lyapunov and Algebraic Riccati Equations
- Optimal and H-infinity Control
- System Identification
- Algorithms for Balanced Realization, Model Reduction and Hankel-Norm Approximations.
- Numerical Algorithms and Conditioning of Pole-placement
- Algorithms for Observer Design, Kalman Filtering and LQG Design item Large-Scale and High-Performance Computing in Control

Software:

- MATLAB-based Control System Toolbox
- SLICOT - A Fortran Subroutine Library in Systems and Control Theory
- Control Systems Professional: Advanced Numerical Methods - A MATHEMATICA Based State-of-the-art Control Library

- MATCONTROL - A MATLAB-based Control Systems Educational Tool Box, developed by Biswa Datta

Intended Audience: Graduate Students and Researchers in control and systems, and practicing control and systems engineers and applied scientists working on a wide variety of control applications, including *aerospace, automotive, biology, medicine, space-sciences, structural and manufacturing engineering, robotics, power systems.* and many others. The course will also be of interests to *applied and computational mathematicians and other scientists* desirous of learning of how linear algebra problems arise in control systems design and analysis and are solved using sophisticated techniques of numerical linear algebra.

Background : A First Course in *Linear Control Systems and in Numerical Linear Algebra* will be helpful. Required numerical linear algebra topics will be reviewed during the lectures, as needed.

Lecture Notes: Detailed Lecture Notes will be provided to the audience.

References:

BOOK: *Numerical Methods for Linear Control Systems Design and Analysis, by Biswa Nath Datta, ELSEVIER/ Academic Press, 2003.*

Software Manuals: *MATLAB Control Systems Tool Box, MATHEMATICA-based Control Systems Professional- Advanced Numerical Methods, and SLICOT.*

A TENTATIVE SCHEDULE

State of the Art Computational Methods and Software for Control Systems

Organizer: *Biswa Datta*

Presented by: *Biswa Datta*

9:00-10:00 - Introduction. Basic Concepts: Modeling; System Responses; Controllability, Observability and Distance to uncontrollability; Stability, Robust Stability and Distance to Instability.

10:00-10:30 - TEA BREAK

10:30 -11:30 - Feedback Stabilization (LQR Design), Numerical Methods and Conditions for Lyapunov, and Algebraic Riccati Equations(and possibly H-Infinity Control)

11:30-12:30 - System Identification

12:30-2:00 - LUNCH

2:00-3:00 - Model Reduction and Hankel Norm Approximation

300-3:30 -TEA BREAK

3:30 - 4:30 - Numerical Methods and Conditioning of Pole Placement. Algorithms for Observer Design, Kalman Filter, and LQG Design.

4:30-5:30 - Control Software

ABOUT THE AUTHOR (Biswa Nath Datta)

Biswa Nath Datta is a Professor of Mathematical Sciences and a Presidential Research Professor at *Northern Illinois University.* Professor Datta held visiting professorship at *University of Illinois* at Urbana-Champaign, *Pennsylvania State University*, *University of California* at San Diego, *State University of Campinas*, Brazil, as well as at many other universities and research laboratories around the world, including the *Boeing Company.* He also held short term distinguished visiting professorship at *University of Adelaide*, Australia, *Universidad Catolica del Norte*, Chile, and *Universidad Polytechnica de Valencia*, Spain, *Tsing Hua University and National University of Taiwan* , Taiwan, and others.

His research interests are interdisciplinary, blending linear and numerical linear algebra with control and systems theory. He was elected to a *Fellow* of IEEE in 2000 for his interdisciplinary contributions. He was elected as an *"Academician"* by the Academy of Nonlinear Sciences in 2002.

Professor Datta is the author of more than ninety interdisciplinary papers and two books entitled **Numerical Linear Algebra and Applications**, published in 1995, and **Numerical Methods for Linear Control Systems Design and Analysis**, published in 2003. He has served in the past or is presently serving on the editorial board of premier journals such as *SIAM J. Matrix Analysis and Applications, Linear Algebra and its Applications (special editor), Numerical Linear Algebra with Applications, the Journal of Mathematical Systems, Estimation, and Control, etc.* He is the Founding Editor and the Editor-in-Chief of the annual series : *Applied and Computational Control, Signals, and Circuits.* He has also edited four interdisciplinary books and several interdisciplinary special issues of some of the above journals. He is also the co-author of the control engineering software package, entitled *"Control System Professional - Advanced Numerical Methods,"* Wolfram Research inc., 2003.

He has delivered numerous invited talks and short courses/ workshops at international conferences and many colloquium talks at universities and research laboratories around the world.

Professor Datta served as the *vice-Chair* of the *SIAM Linear Algebra Activity Group*, as the *Chairman* of the of the committee of the SIAM Prize for the Best Applied Linear Algebra Paper and a member of the Hans Schneider Prize Committee in Linear Algebra.

He also organized and chaired or co-chaired the *AMS -IMS-SIAM Joint Summer Research Conference on Linear Algebra and Its Role in Systems Theory*, 1984 ; the *SIAM Conference on Linear Algebra in Signals, Systems, and Control*, 1986, 1988, 1993, 2001; *Mathematical Theory of Networks and Systems(MTNS)*, 1996, and numerous interdisciplinary invited special sessions on
control, systems, and signal processing at several AMS, SIAM, IEEE, International Federation of Automatic Control, and MTNS conferences.