WORKSHOPS

Tutorial Workshops: September 24, 2002, ASCC, Singapore
http://ascc2002.nus.edu.sg/workshops.html

No.	SPEAKER(S)	TITLE	Fee	Venue	Time
F1	Miroslav Krstic	Nonlinear Backstepping Designs and Applications: Adaptive, Robust, and Optimal	S$300.00		9.00am – 5.30pm
F2	Takashi Yamaguchi & Guoxiao Guo	Introduction to hard disk drive servo system - Fundamentals and frontiers of hard disk servo systems	S$300.00		9.00am – 5.30pm
H1	Dave Glanzer	FOUNDATION™ fieldbus: Open Fieldbus Architecture For Information Integration	S$150.00		2.00pm – 5.30pm

The Abstracts of the talks and the biographies of the speakers are given as follows.

Workshop F1

Nonlinear Backstepping Designs and Applications:
Adaptive, Robust, and Optimal

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Over the past ten years, the focus in the area of control theory and engineering has shifted from linear to nonlinear systems, providing control algorithms for systems that are both more general and more realistic. Nonlinear control dominates control conferences and has strong presence in academic curricula and in industry.

This tutorial will teach the participants the design tools for control of nonlinear systems with uncertain models that every graduate student or control practitioner today must know. The tutorial will also put research-oriented participants on a fast track towards some of the open problems in the area. The tutorial content consists of essentials scattered in some 20 textbooks and monographs published in the last decade on nonlinear and adaptive control. Familiarity with the basic Lyapunov stability concept is the only prerequisite required to follow the tutorial. The tutorial topics have been class tested in the instructor's one year long graduate sequence on nonlinear and adaptive control at University of California, San Diego, and at similar workshops he has presented at conferences in the United States and several other countries. The past participants of these workshops include many of the leading researchers in the control area.

Backstepping is a design approach whose significance for nonlinear control can be compared to root locus or Nyquist's method for linear systems. Its roots are in the theory of feedback linearization of the 1980's. With its added flexibility to handle modeling nonlinearities and some classes of systems that are not feedback linearizable, backstepping is the most important ingredient in the nonlinear control advances of the last decade.

We first present algorithms for adaptive nonlinear control. Lyapunov-based tools such as the tuning functions method are covered in detail, which allow simultaneous design of adaptive controllers and parameter estimators, and as a result lead to the strongest performance properties among the methods for adaptive control. This is followed by modular methods that recover a linear-like controller/estimator separation principle---but with a twist. Special controller strengthening allows the use of any parameter estimator, even in the presence of rapidly growing nonlinearities.

Robust nonlinear control is covered next in the form of disturbance attenuation. It is explained how other forms of uncertainties (functionally uncertain nonlinearities, un modeled dynamics, etc.) can be handled using a nonlinear extension of the small gain theorem. A general framework is presented for achieving a strong form of disturbance attenuation called input-to-state stability. Backstepping is used to develop control algorithms for disturbance attenuation in a specific, broad class of systems. Nonlinear systems with two types of disturbances are treated: deterministic and stochastic. The stochastic case will particularly reveal the power of the backstepping method, which, in combination with elements of Ito's calculus, turns some notoriously difficult nonlinear stochastic problems into easy exercises.

Optimal control formulations for nonlinear systems produce solutions (based on Hamilton-Jacobi nonlinear partial differential equations) that are seldom feasible, even numerically. It will be shown how the backstepping approach, in turn, produces closed-form solutions to inverse optimal control problems. These controllers have familiar gain and phase robustness markings, the classical benefit of optimality discovered by Kalman for linear systems. Using backstepping one can even obtain explicit control laws that solve the nonlinear H-infinity problem.

Nonlinear observers and output feedback is a tool of great practical necessity and a major open research problem. Output feedback design is covered both in the context of adaptive control and disturbance attenuation.

Forwarding is a procedure applicable to a class of systems dual to those tractable by backstepping. A compact presentation of forwarding will be given, fully exploiting the analogy with backstepping, which will introduce the participants to this procedure in a manner much clearer, simpler, and more accessible than in any other resource available.

In terms of industrial and applications impact over the past decade, backstepping and nonlinear control rank at the top among control theoretic design tools. Examples of uses of backstepping will be presented from among the long list of applications that have emerged recently: marine vehicles, satellites and airplanes, automotive problems, electric machines and robotics, jet engines, fluid and thermal problems, bioreactors, and even fusion reactors.

Tutorial participants will receive typed, book-like notes specially prepared for this tutorial. A literature summary for further self-study will be included.

Miroslav Krstic is Professor and Vice Chair in the Department of Mechanical and Aerospace Engineering at University of California, San Diego. Prior to moving to UCSD, he was on the faculty of the Department of Mechanical Engineering and the Institute of Systems Research at University of Maryland.

Krstic got his PhD in Electrical Engineering from University of California at Santa Barbara, under Petar Kokotovic as his advisor. His dissertation received the UCSB Best Dissertation Award.

Krstic is a recipient of several paper prize awards, including the George S. Axel by Outstanding Paper Award of IEEE Transactions on Automatic Control, and the O. Hugo Schuck Award for the best paper at American Control Conference. He has also received the National Science Foundation Career Award, Office of Naval Research Young Investigator Award, and is the only recipient of the Presidential Early Career Award for Scientists and Engineers (PECASE) in the area of control theory.

Krstic is a co-author of the books Nonlinear and Adaptive Control Design, Wiley, 1995 and Stabilization of Nonlinear Uncertain Systems, Springer-Verlag, 1998 and over 120 refereed papers. He has two patents on control of aeroengine compressor and combustion instabilities.

He has served as Associate Editor for the IEEE Transactions on Automatic Control, International Journal of Adaptive Control and Signal Processing, Systems and Control Letters, and Journal for Dynamics of Continuous, Discrete, and Impulsive Systems. Krstic served for three years as the Chair of the committee for the IEEE Conference on Decision and Control Student Best Paper Award. He is a member of the Board of Governors of the IEEE Control Systems Society.

Krstic's research interests include nonlinear, adaptive, robust, and stochastic control theory for finite dimensional and distributed parameter systems. He teaches graduate courses in all of these areas at UCSD. Krstic is active in control applications to propulsion systems, fluid flow, marine and aerospace vehicles, bioengineering, and fusion/plasma engineering.

Workshop F2

Introduction to hard disk drive servo system
- Fundamentals and frontiers of hard disk servo systems

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HDDs have been widely used as a data filing and retrieval systems. Over the past few decades since it was invented in 1956, the recording density (the product of the linear density measured by the bits recorded per inch or BPI, and track density measured by the number of data tracks per inch or TPI), has grown tremendously. By the end of year 2001, the highest area density demonstrated in laboratory was over 100 Gb/in^2, at a track density of 155,000 TPI. This translates to a track width of narrower than 6.5 microinch or 0.16 micrometer, and a 16 nanometer positioning accuracy if a 10% track width error is allowed.

The mechanical system of an HDD must move the head from one track to another as quickly as possible, and keep the head on center of the track as precisely as possible. Over the past 10 years, the TPI has been improved by about 30-40% per year, and the average seek time has been improved to 1/3. Mover over, these motions should be maintained under variations of environment around the HDD such as vibrations and temperature.

Over the years, considerable improvements in the high bandwidth actuator design (which reduced the plant model uncertainty), low vibration level hard disk media (which reduced the movement of the target for the servo system to follow), airflow (which reduced the disk vibration as well as the torque disturbance to the actuator) and low noise electronics have been made. Compounded with the friendlier plant under control, the control design itself has evolved from traditional PID compensator to higher order, phase stable designs, and with various peak filters to deal with various resonant modes, and mode switching control to deal with the various initial values, for transient performance improvement. As one sign of the sophistication of the HDD servo system, it is very common to see a digital signal processor in the HDD printed circuit board for control calculation because of the computational power needed. Nowadays, there is no surprise to see an HDD voice coil motor control loop having a compensated open loop 0-dB crossover frequency of above 1,000 Hz, working at higher than 20 kHz sampling frequency using a controller of higher than 7th order with a number of mode switches.

When dealing with HDD servo mechanical systems, both optimality and robustness need to be guaranteed. Ensuring the closed-loop system stability, when the controller is down loaded to millions of drives, is not enough--- each drive's servo has to perform at its tiptop condition of performance for the whole batch of drive, for the product to roll out of the production line.

This workshop aims at explaining the basic operations of hard disk drive servo mechanical system, and the various how and what that drove and driving the ever improving nano-positioning system. We will cover the following topics:

- Basic of HDDs
- Modeling and identification of HDD actuators
- Obtaining the position error signal
- Vibration sources and identification
- PID control versus optimal loop shaping control
- Phase stable servo system
- Seek control, and mode switching control
- Repetitive control and run out compensation
- Limitations of control
- Mechanical improvements to enhance the TPI
- Dual-stage actuators and control designs
- Control designs for the servo track writing process

Takashi Yamaguchi was born in Tokyo, Japan, in 1956. He received the B.S., M.S., and Dr. Eng. degree from Tokyo Institute of Technology in 1979, 1981, and 1998 respectively. From 1981, he has been with Mechanical Engineering Research Laboratory, Hitachi, Ltd. From 1986 to 1987 he has been an industrial visiting researcher in University of California, Berkeley. From 1993 to 1996 he has been an engineering manager at Data Storage & Retrieval Systems Division, Hitachi, Ltd.

Dr Yamaguchi received engineering awards from Japan Society of Mechanical Engineers and Society of Instrument and Control Engineers in 2000 and 1997 respectively. His research interests include servo control technology for information devices such as HDD, and a design methodology for motion control such as head-positioning system on HDD.

Guoxiao Guo was born in 1967 in P R China. He received the B.Eng. and M.Eng. Degrees from Tsinghua University, Beijing, P R China in 1989,1994 respectively and Ph.D. degree from the Nanyang Technological University, Singapore, in 1997.

He joined the Data Storage Institute (DSI) of Singapore in 1995 as a Research Engineer. Since April 1999 he has been the Manager for the Servo Electronics Group and now the Mechatronics and Micro System Group. His research interests include vibration analysis and control for electric drive systems, precision motion control, applied control theory and Mechatronics, with special focus on nano-positioning systems for rotating data storage devices.

Workshop H1

FOUNDATION™ fieldbus:
Open Fieldbus Architecture For Information Integration

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Integration of information from sensors, automatic process and discrete control systems, supervisory and batch systems, resource planning systems and management information systems is required for plant optimization. The primary barrier to integration in the past was the lack of open specifications for the fieldbus system used for interconnecting the automation equipment.

Open specifications enable control devices from different manufacturers to interoperate on the same network without the need for custom programming. The specifications must included communications system and the "user layer" above the communication system. The communication system simply moves data from point A to point B. It is the User Layer that enables distribution of control functions into control devices and provides the common function block language.

FOUNDATION fieldbus provides open specifications for a 31.25 Kbit/s fieldbus (H1) and a 100 Mbit/s fieldbus called High Speed Ethernet (HSE).

H1 is optimized to handle distributed process control applications. The H1 physical layer signaling, data link and messaging protocols are specified in the approved ISA SP50 and IEC 61158 standards. The User Layer specification provides the function blocks and device descriptions necessary for interoperability at this level. The User Layer specifications have been released by the Fieldbus Foundation.

HSE running at 100 Mbit/s is designed for advanced hybrid, batch and manufacturing applications. Linking devices are used to interconnect multiple H1 fieldbus segments to HSE. A "Flexible Function Block" (FFB) implements control strategies based on programming standards such as IEC 61131. FFBs support such functions as supervisory data acquisition, I/O subsystem interfaces, sequence of events and coordinated drives. They also allow multiplexers, PLCs and gateways to other protocols to use the HSE backbone.

HSE physical layer signaling and data link protocols are specified in IEEE 802.3 and ISO/IEC 8802-3 standards. HSE uses standard Internet protocols including TCP/IP, UDP, and SNTP. The use of standard Ethernet/Internet protocols allows HSE fieldbus networks to be built using Commercial Off The Shelf (COTS) Ethernet cable, switches and routers. HSE supports fault-tolerant networks and redundant HSE devices for mission-critical monitoring and control applications. Using standard Ethernet wire and fiber optic media, fault-tolerant HSE control networks of any topology or size can be created.

H1 fieldbus combined with linking devices, gateways and fault tolerance, make the Fieldbus Foundation's HSE technology well-suited as the plant control backbone. HSE's bandwidth capabilities enable the transfer of large files and high speed I/O such as analyzers and PLCs. Moreover, its use of standard fieldbus function blocks, such as AI, AO and PID, and the FFB, ensures a uniform presentation of data at all levels of the control network.

Dave Glanzer is the Director of Technology Development at the Fieldbus Foundation (Austin, TX). He is responsible for development of the foundation’s technology-based specifications and products. Mr. Glanzer is a BSEE and is a member of American Society for Quality (ASQ), and is a Senior Member of the International Society for Measurement and Control (ISA).