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Åström, Karl Johan

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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

VISIT TO CHINA APRIL 1980

KARL JOHAN ÅSTRÖM

DEPARTMENT OF AUTOMATIC CONTROL
LUND INSTITUTE OF TECHNOLOGY
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Abstract A4 A5 <p>The report summarizes experiences from a visit to China in April 1980. Most of the time was spent at the Laboratory of Control Theory of the Academia Sinica in Peking, where a series of lectures on Stochastic Control Theory was given. Visits to Pekins Steel Research Institute, Peking Organic Chemical Plant, Tsinghua University, Shanghai Ship Design and Research Institute, and Shanghai Jiao Tong University are also reported.</p>		
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V I S I T T O C H I N A A P R I L 1 9 8 0

Karl Johan Aström

1. INTRODUCTION

On the invitation of prof Kwan Chao-chih I visited the Laboratory of Control Theory of the Institute of System Science and Mathematics of Academia Sinica in Peking. The main purpose of the visit was to give a series of lecture on stochastic control theory and to discuss with the researchers of the laboratory. During my visit there was also opportunities to visit universities and industries. I would like to express my sincere gratitude to prof Kwan for inviting me and to the Swedish Board of Technical Development (STU) who provided travel support (Contract 79-5752). I am also most grateful to my chinese colleagues, who spent much time talking to me and for the great hospitality that was always given to me. I am particularly grateful to prof Chen Han-fu, who accompanied me on several trips. This gave a good opportunity to persue culture, Chinese history, Chinese chess, and table tennis as well as stochastic control theory.

2. THE LABORATORY OF CONTROL THEORY

The Control Theory Laboratory was founded in 1962 as part of the Institute of Mathematics of Academia Sinica on a suggestion from prof Tsien. In october 1979 a new Institute of System Science and Mathematics was formed and the Control Theory Laboratory became part of it. The new institute has the following laboratories:

- Control Theory
- Operations Research Mathematics
- Operations Research Management Science
- Statistical Mathematics
- Mathematical Physics
- Computer Science

Prof Kwan Chao-chih is director of the Laboratory of Control Theory. At the time of my visit the laboratory had 26 staff members and 6 students. A survey of the activity over the past two years are given in the activity report [1], which also contains a publications list. The major research areas are:

- Linear system theory

Stochastic control theory
 Distributed parameter systems
 Nonlinear systems
 Information processing
 Differential games
 Applications of modern control theory

The groupleader in linear system theory is prof Han Jing-qing. One major activity of the group is to unify the different approaches to linear system theory and to provide suitable algorithms for numerical computations. Among specific problems that have been investigated are linear polynomial equations.

Prof Chen Han-fu is the leader of the group in stochastic control theory. The LQG problem has been investigated. Problems with unknown initial conditions and singular control problems have been studied. Stochastic realization theory, system identification, and stochastic differential games have been investigated. Some recent work in stochastic control theory is listed in the references of this section.

The research in distributed parameter systems is directed by prof Kwan. The problems that have been investigated include control and stabilization of elastic beams, temperature control in gyroscopes, sensor and heater placement for temperature control of floating gyros, optimal power distribution in nuclear reactors, and control of slender space vehicles.

Dr Chin Hua-shu leads the research in nonlinear systems. Current research is centered on bifurcation and stability theory. Rigorous conditions for the validity of describing function analysis have also been established.

There are several projects which are devoted to explore the practical application of modern control theory. Applications to navigation and guidance, to tandem cold rolling have been investigated. Stability theory and nonlinear estimation theory have been applied to power systems.

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Academia Sinica, Peking 1980.

3. THE LECTURES

Eight lectures were given on stochastic control theory and its applications. A résumé of the lectures is given in Appendix A of this trip report. The overhead transparencies used in the lectures are available as a report. See [1]. A general lecture on trends in automatic control was also given at the Institute of System Science and Mathematics. The lectures lasted for a morning or an afternoon each. I spoke in English and prof Chen Han-fu translated simultaneously. After some experimentation this worked very well. I am most grateful to prof Chen Han-fu for his excellent help. There were about 150 persons in the audience. They came from many parts of China. There were representatives both from the research institutes of the Academia Sinica, the universities and the industries. The audience was very captive. Several of the papers which formed the basis of the lectures had been translated to Chinese beforehand. There were many good and penetrating questions. A substantial part of the lectures dealt with my own research that had been supported by STU. The lectures gave an excellent opportunity to organize all the material into a coherent picture. I was also fortunate to have time to write up the material and to work it into the forthcoming Chinese translation of my 1970 book Introduction to Stochastic Control Theory. The translation is made by prof Pan Yu-huan of Shenyang Institute of Automation and I had good opportunities to discuss with him. The Chinese translation will thus be up to date. It will contain five new chapters. I found particular interest from the audience in those parts of the theory that had found practical application.

Trends in Automatic Control

Prof Kwan wanted me to give a special lecture outlining my personal perspective on the future development of the field of automatic control. This lecture was not planned beforehand, neither did I have time to write it up. An account of the main contents of the lecture is therefore listed below.

- Introduction
- Relations to other fields
- General theoretical problems
- Modeling and identification
- Computer aided design
- More complex regulators
- Conclusions

In summary the lectures were a very stimulating experience. Organizing them presenting them and writing them up gave an excellent opportunity to get a coherent picture of research that stretched over several years.

Reference

1. Aström, K J, Overhead slides for eight lectures on stochastic control theory and applications. Report TFRT-7204, Dept of Automatic Control, Lund Institute of Technology, Lund 1980.

4. DISCUSSIONS

There were many opportunities for discussions both formal and informal. One morning and one afternoon were set aside for organized discussions. There were also many informal discussions in connection with the lectures and at during the time I was at the institute. One of the formal discussions was devoted to research at the Institute of System Science and Mathematics. The other to work in my own areas of specialization. Some of the topics discussed are listed below:

- Temperature control of ovens.
- Identification of asymmetric systems.
- Stability of adaptive control systems.
- Solution of linear equations in polynomial matrices.
- Systems with rapidly changing parameters.
- Approaches to control of multivariable systems.
- Control of ship steering.
- Impact of microprocessors on control systems.
- Adaptive control.
- Self-tuning regulators.

The names of some of the researchers I discussed with are

listed in Appendix B. Mr Nils Ekblad of the Swedish Embassy also participated in one of the discussions.

5. VISIT TO PEKING STEEL RESEARCH INSTITUTE.

There were several researchers from the Peking Steel Research Institute who attended my lectures. Dr Zhong kindly invited me to visit the institute. I was received by Prof T Ko, Vice President and Dean of the Faculty of Metal Physics and Chemistry. He had organized a general tour of the different laboratories of the Institute. There was a computing centre with a RS 131 computer (32 k 16 bit words similar to DG Nova). There was also a special laboratory for identification of rolling mill dynamics. The techniques used were based on correlation methods. The instruments were manufactured at the Institute. They had been used for laboratory experiments and for plant experiments. A typical application was to determine the relation between sheet thickness and screw-down position. A particular problem that had been encountered was that the dynamics depended on the sign of the derivative of the input signal.

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6. PEKING ORGANIC CHEMICAL PLANT

A visit was arranged to the plant because they had experimented with self-tuning regulators (developed under STU contract 70-337/U270). The plant produces polyvinylacetate. The plant has a nominal capacity of 10000 tons. It was started in 1965. The production has been

doubled since then. The plant has conventional instrumentation. A process computer was installed in 1970. The plant has a research department which does advanced control work. Work on self-tuning regulators have been made in collaboration with the Mathematics Department of Nankai University. A self-tuner based on minimum variance control and least squares parameter estimation has been tried. The regulator has been applied to level control in an acetic acid evaporator and to temperature control in a vinyl acetate synthesis reactor. Good results have been reported.

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Self-tuning Adaptive Control of two Installations in
Chemical Industry.
Report Nankai University. Submitted to IFAC.

7. TSINGHUA UNIVERSITY

The university grew out of Tsinghua College which was founded in 1911. It received university status in 1928. Today the university has a faculty of about 3000. There are over 6000 undergraduates and about 600 graduates. The university has the following departments.

- Civil Engineering and Architecture
- Hydraulic Engineering
- Mechanical Engineering
- Precision Instruments
- Thermal Energy Engineering
- Electrical Power Engineering
- Radio Electronics
- Computer Engineering and Science
- Automation
- Engineering Physics
- Chemical Engineering
- Engineering Mechanics

There are 9 research institutes and 9 workshops within the university. The workshops support teaching and research but trial productions are also done in them. The university has a journal (J of Tsing Hua University) and a report series called Science Reports of Tsinghua University.

I visited the laboratories of Systems Engineering, Industrial Control and Industrial Instruments, and the laboratory of Precision Instruments. I also had discussions with some members of the Department of Automation. The university has good computer facilities. The Department of Automation has an analog computer DMJ-3A with about 40 integrators and a minicomputer DJS 131 with 32 k 16 bit words. There were plans to connect them to a hybrid system.

The Department of Computer Science has a PDP 11/45, six LSI 11, and several Cromenco microcomputers. I also saw an Apple II with color graphics for speech recognition. It was particularly interesting to see that the university had manufacturing facilities. A 4 k ROM was for example produced. In the Department of Precision Instruments an electrostatically suspended gyro was also made.

8. SHANGHAI SHIP DESIGN AND RESEARCH INSTITUTE

The institute is the national institute for ship design. It also has research missions which are similar to those of SSPA in Sweden. There are about 1600 persons working at the institute. There is a group of about 24 persons for research in problems related to automatic control. Dr Sun Songhe is the manager of this group. I was kindly invited to discuss with the group.

The institute works with all aspects of ship design. Automation has only recently been considered as an important part of shipbuilding. This explains why the proportion of the total staff that works on automation was so small. The interest in automation is however steadily increasing. It was considered to make extensive use of microprocessors for automating many functions on the ship. An overview was given of some projects that were considered. These include automation of

- engine room
- cargo handling
- stabilization tanks
- steering

The possibilities of having unattended engine rooms was investigated. Cost effectiveness of different degrees of automation was also studied.

The feasibility of having fully automatic loading and unloading was explored both for cargo handling and for oil and chemicals. Since large information processing capacity was needed the computers will be land based. The possibilities of integrating cargo handling with control of the ship operation was also investigated. Automatic control of oil handling was one of the important research projects in the area.

In the field of steering work was currently concentrated on dynamic position keeping.

The methods used by the automatic control group was mostly classical control theory but there was substantial interest to investigate the possibilities of modern control theory.

I also gave an informal seminar about our research in identification of ship steering dynamics and adaptive ship steering. There was considerable interest in both areas. There were many questions on the work on adaptive ship steering that we did jointly with Kockum AB.

9. SHANGHAI JIAO TONG UNIVERSITY.

Professor Chang Tsun-tsing had kindly invited me to visit the university. The university, which was founded in 1896, is an institute of technology organized similar to MIT. There are 13 departments:

- Naval Architecture
- Marine Power Engineering
- Electrical Engineering and Computer Science
- Electronic Engineering
- Material Science and Engineering
- Mechanical Engineering
- Applied Mathematics
- Precision Instruments
- Applied Physics
- Engineering Mechanics
- Industrial Engineering
- Applied Chemistry
- Foreign Technical Languages

A school of Management and Industrial Engineering has also been added.

Department of Electrical Engineering and Computer Science

The department has 40 professors, 1300 undergraduates, and 50-60 graduate students. The undergraduate curriculum takes 4 years and a MS degree an additional 2 years. Prof Chang is the department chairman. The department has three major research groups: Power Systems, Control Systems and Computer Science. There are also several laboratories.

The power systems group has a large analog power systems simulator. There are 6 generators, lines and different loads. The generators' power are in the range 5-30 kW. Analog computers are used to simulate governors and voltage regulators. The lines are simulated using large LC-networks. The loads are simulated using motors, resistors and lamps. The facility is used both for research and teaching. Nine persons are required full time to run the facility.

The control group has also good experimental facilities. There is a computer lab with an DJS-130 with discfiles and 26 terminals. The languages Basic, Fortran and Algol are used together with a real time operating system similar to Argus. An analog computer laboratory has a DMJ-3A with 40 amplifiers and several 6 amplifier DMJ-16B. The analog

computers are used for courses and research. There is also a servolaboratory with servomotors and special simulators for low order systems.

The computer science group has Wang computers with many peripherals, printers, plotters, discs and terminals. Algol used to be the dominant language but a switch to Basic, Fortran and Cobol was recently made.

I had a long discussion with the teachers in the control group on education and research in automatic Control. A list of the participants are given in Appendix B. We discussed teaching of modern and classical control in depth. I also gave an informal seminar on Research in Automatic Control in Sweden. Some of the reseach projects under investigation are listed below.

- Adaptive control using microprocessors
- Control of SCR's
- Control of Speed drives for paper mills
- Digital and hybrid simulation
- Computer aided design of control systems
- Large scale systems
- Microprocessors for control

The control group had collaboration with many other groups at the university. Identification of gyro drift was e.g. done together with applied mathematics.

10. SHANGHAI SOCIETY OF AUTOMATION

The society serves universities, colleges and industries with interest in automatic control. It works like professional organizations as IEEE and IEE. I was invited to give a lecture on adaptive control to the society. An outline of the lecture is given below.

- Introduction
- Principles of adaptive control
- Examples
- Theory of adaptive regulators
- A review of applications of adaptive control
- Conclusions

About 100 persons attended the lecture. There were several questions related to practical aspects of adaptive control.

A P P E N D I X A

EIGHT LECTURES ON STOCHASTIC CONTROL THEORY
AND ITS APPLICATIONS

K J Aström

LECTURES 1 & 2 - LINEAR STOCHASTIC CONTROL THEORY

The major results of linear stochastic control theory are reviewed. Emphasis is given to the problem formulation and to the main mathematical models used. The topics covered include minimum variance control, Kalman filtering, and the separation theorem. The problems are discussed both from the input-output and the state space point of view. The presentation is based on references [1], [2], and [3].

LECTURE 3 - MODELING AND SYSTEM IDENTIFICATION

The problem of obtaining the mathematical models used in linear stochastic control from experimental plant data is discussed. Principles of parameter estimation are discussed. The techniques include maximum likelihood and prediction error methods. Theoretical results for large sample properties are discussed together with computational and practical aspects. The presentation is based on references [4] and [5].

LECTURE 4 - APPLICATION OF PARAMETER ESTIMATION METHODS TO DETERMINE SHIP STEERING DYNAMICS

Application of the methods described in lecture 2 to determination of mathematical models for ship steering dynamics. The topics discussed include: mathematical models for ship dynamics, disturbances due to wind and waves, parameter estimation and practical aspects on parameter estimation. The presentation is based on references [6], [7], and [8].

LECTURE 5 - NONLINEAR STOCHASTIC CONTROL THEORY

Some important results in nonlinear stochastic control theory are discussed. The structure of the optimal feedback is derived for processes described by Markov chains using Dynamic programming. Nonlinear filtering and the nature of

the solutions for more general problems are treated. Concepts of certainty equivalence, caution and probing are introduced. The presentation is based on reference [2].

LECTURES 6 & 7 - SELF-TUNING AND ADAPTIVE CONTROL

Principles of adaptive control are introduced based on nonlinear stochastic control theory. Self-tuning regulators are introduced as an approximation to the general nonlinear problem. It is also shown that self-tuning generators can be motivated in more general cases. Relations to model reference adaptive systems is discussed. Theory of adaptive control and its short-comings and applications are reviewed. The presentation is based on reference [9].

LECTURE 8 - DESIGN OF AN ADAPTIVE AUTOPILOT FOR SHIP STEERING

Describes the application of adaptive control to a practical problem. The autopilot includes gain scheduling to eliminate influence of velocity variations, a Kalman filter, and a self-tuning regulator. The design trade-offs are discussed. Results from full-scale experiments on several ships are described. The presentation is based on reference [10].

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A P P E N D I X B

PARTICIPANTS IN DISCUSSIONS IN PEKING

Kwan Chao-chi
Chin Hua-shu
Han Jing-qing
Chen Han-fu
Xu Ke-kang
Zheng Chao-zhou
Wang En-ping
Zang Yong-guang
Institute of System Sciences
Academia Sinica, Peking

Yuan Zhen-dong
Department of Mathematics
Shanghai Normal University
Stochastic Control. Identification.

Pan Yu-huan
Shenyang Institute of Automation
Academia Sinica, Shenyang
Stochastic control. (Translates my book)
Computer control of industrial processes.

Ma Chih-heng
Kai-shan Gueishou
Autopilots.

Feng Chun-bo
Nanking Institute of Technology
Adaptive flight control systems.

Wan Bai-wu
Institute of Systems Engineering
Xian Jiao Tong University
Stochastic control. Identification.
Population dynamics.

Li Hsi-wu
Scientific Research Institute of Electric Power
Qinghe, Peking
Boiler dynamics and control.

Liu Zheng-yuan
China Ship Scientific Research Center
PO Box 116
Wuxi
Identification of ship steering dynamics.

To Ke-lai
Department of Automation
China University of Science and Technology
Heifei, Anhui
Identification of ship steering dynamics.

Fan-jung
The Northwest Industrial University 901
Xian
Multivariable stochastic systems. Microprocessors.

Zhou Qi-jie
Department of Automatic Control
Huanan Institute of Technology
Kuangzhou
Multivariable minimum variance control.

Lin Tao Wan
Department of automatic control
Nanking Aeronautical College
Adaptive flight control.

Wang Shou-tung
Wang Wen-xiao
Xia Yan
Shipbuilding Industry Company of China
North yue-tan street Peking
Inertial navigation.

Yuan Zhu-zhi
Department of Mathematics
Nankai University
Adaptive control. Self-tuners.

Chen Zhen-yu
PO Box 919
Peking
Tuning of feed-forward loops.

Du Yee-min
Aeronautical Institute of China
PO Box 030-5
Laoyang, Henan
Remote control via modem.

Zhang Zheng-fang
Research Institute of Extensions and Applications
of Electronic Technology
PO Box 927
Peking
Process control in the paper industry.

Feng Xi-sheng
Xu Yi-fei
Northern Jiaotong University
Autopilots for ship steering.

Yu Sen-fen
Institute 702
6th Industrial Ministry
Wuxi, Jiangsu
Autopilots.

Lee Wen-ching
Department of Mathematics
Amoy University
Fujian Province
Stochastic control theory. Algebraic system theory.

Wu Hung-sin
Peking Institute of Control Engineering
Peking
Recursive estimation. Self-tuning control.
Vacuum oven.

Hian Ze-gang
Applied Mathematics Research Institute
Xai Ling Jiang University

Lu Gui-zhang
Nankai University

Ying Shu-guang
Peking Organic Chemical Plant
Self-tuners.

Fang Xiang-lin
Institute of seairtransportation
Dalian

Xu Wen-yuan
Institute of System Sciences
Peking

Chong Yan-jone
Peking Institute of Iron and Steel
Identification. Rolling mills.

Wu Guang-yu
Harbin University of Industrial Engineering
Harbin

Wang Shun-liao
Ship Building Industry Company of China
Peking

Lin Dao-yuan
Nanking Institute of Aeronautics

Feng Chun-bai
Nanjing Institute of Industrial Engineering

Huo Huan-jiao
Shanghai Jia Tong University

Gao Long-hai
The Great Wall Company

Huang Ji-qi
Shipbuilding Society Wuhan

Zhang Ahi-fang
Department of Automatic Control
Peking Institute of Technology

Hou Ye-he
Harbin Institute of Ship Engineering

Tian Cheng-jun
Department of Mathematics
Shanxi University

Han Zi-gan
Den Zi-li
Heilongjiang Institute of Applied Mathematics
Heilongjiang University
Self-tuning control.

PARTICIPANTS IN DISCUSSIONS IN SHANGHAI

Prof Chang Tsung-tsing
Chairman of Electrical Engineering and Computer Science
Shanghai Jiao Tong University, Shanghai

Xu Jun-rong
Automatic Control

Shi Song-tiao
Automatic Control

Chang Kai-pong
Mathematics

He Huan-hei
Mathematics