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# Travel Report from London

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<i>Title and subtitle</i> Travel Report from London		
<i>Abstract</i> <p>This report gives a summary of Anders Hansson's visit to Imperial College of Science, Technology and Medicine, London. An overview of the research together with a summary of impressions are given.</p>		
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## 1. Introduction

During 6 months, from October 1992 to March 1993, I had the privilege to visit Professor Mark. H. A. Davis at the Department of Electrical Engineering at Imperial College of Science, Technology and Medicine, London, U.K. The travel was possible due to support from

- Landshövding Nils Hörjels forskningsfond
- The Swedish Institute
- Lund University

I want to express my sincere gratitude for this support and to thank Professor Mark. H. A. Davis for accepting me as an occasional student.

Section 2 contains a brief description of the research done during my stay in London. Imperial College is described in Section 3. Section 4 contains some conclusions.

## 2. Research

During the stay at Imperial College I mainly worked with non-linear stochastic control of critical processes under the supervision of Prof. Davis. I also followed a lecture series on stochastic differential equations given by Prof. Davis. Both activities are described in more detail below.

### Stochastic Differential Equations

Stochastic Differential Equations facilitates modeling of continuous time dynamic systems driven by not only measurable signals but also by stochastic unknown signals, whose only known properties are that they are Brownian motion with a certain incremental covariance. This is a nice way of modeling uncertainty which has proven to be fruitful. Brown was 1828 the first to use this type of models, and he used it to describe the irregular movement of pollen, suspended in water. Brownian motion has been further studied by Bachelier, 1900, who considered stock prices fluctuations, and by Einstein, 1905, who investigated the molecular-kinetic theory of heat. A rigorous treatment of Brownian motion was given by Wiener, 1923. Stochastic differential equations was developed by Ito, 1942. This type of models has also been used in control theory. Pioneering work was done by Howard 1960, and Girsanov, 1961, who constructed a general theory for continuous time stochastic optimal control based on Bellman's principle of optimality from 1957. This theory have had a great impact on the research in automatic control. Among early applications can be mentioned control of space-crafts.

The lecture series given by Prof. Davis was an introduction to the theory of stochastic differential equations with applications to finance and optimal stochastic control. The course material was [Oksendal, 1989], which provided a nice engineering introduction to the topic. The theoretical gaps in the book were thoroughly filled out during the lectures. The theory which I learnt during the lecture series was fruitfully applied to my research. This made the lecture series very interesting to follow. The application to my research will be described in more detail below.

## **Non-Linear Stochastic Control of Critical Processes**

Many processes in industry are critical. They are often critical in the sense that they have a limiting level. This can be either physical or artificial. Examples of the former are such levels that cannot be exceeded without catastrophic consequences, e.g. explosion. One example on the latter is alarm levels, which if they are exceeded will initiate emergency shutdown or a change in operational conditions. Another example is quality levels, which if they are exceeded will cause unsatisfied customers. Common to the critical processes are that they enter their critical region abruptly as a signal exceeds a limiting level.

In a deterministic framework control of this type of processes has been treated in e.g. [Vidyasagar, 1986; Dahleh and Pearson, 1987; Liu and Zakian, 1990]. Common to the deterministic problem formulation is the design for worst case disturbances, which may seem somewhat too conservative. The classical way to overcome this is to consider a stochastic formulation. This has been described in [Hansson, 1992; Hansson, 1993a], where linear controllers were considered. The aim for my visit to Imperial College was to investigate what could be gained by considering non-linear controllers. In the continuous time case some results were already known, [Heinricher and Stockbridge, 1991]. In the discrete time case no results were known. The outcome of my research can be summarized in

- Generalization of the results in [Heinricher and Stockbridge, 1991].
- Explicit solution of a general full information problem in discrete time
- Insight into non-linear filtering for estimation of maxima

Further details can be found in [Hansson, 1993b]. During my visit an undergraduate student project in Adaptive Control of Upcrossings under the supervision of Prof. Davis was initialized.

### **3. Imperial College**

I visited the Control Section of the Department of Electrical Engineering. Together with the Control Section of the Department of Chemical Engineering this section founded in 1989 the Interdisciplinary Research Centre (IRC) in Process Systems Engineering. The involvement in the IRC has brought the Control Section the benefits of an enlarged research staff population, and the stimulus of exposure to new research problems in the process systems area. For more information about the IRC, see [Centre for Process Systems Engineering, 1992].

#### **Staff**

The staff of the Control and Instrumentation Sections of the Department of Electrical Engineering consists of three professors, one reader, three senior lecturers, two lecturers, and one senior research fellow.

#### **Research**

The research interest at the Control and Instrumentation Section are

- Multivariable System Design
- Optimal Control
- Adaptive Control & Stochastic Systems

- Industrial Systems
- Microelectronics Applications

A brief description of the different fields are given below.

**Multivariable System Design** The different projects in this field are Vertical Stabilization of the Net Tokamak, The Super-Optimal Distance Problem in  $H^\infty$  Control,  $H^\infty$  Control for Time-Varying Systems, A Descriptor Approach to the Solutions of Discrete Time Distance Problems, Multivariable Process Control using  $H^\infty$ , Computer Aided Control System Design, Robust Process Control, A Nash Game Approach to Mixed  $H_2/H^\infty$  Control, Model Reduction for very Large Scale Systems, A Structured Approximation Problem with Applications to Frequency-Weighted Model Reduction, Minimax Terminal State Estimation and  $H^\infty$  Filtering,  $H^\infty$  Identification, Convex Programming Algorithms for Nonlinear and Robust Control, Flight Control using Spoilers, Nonlinear and Adaptive Control of Robots, and Design of Nonlinear Control Systems. The senior people of the Control Section working in these areas are mainly Dr. D. J. N. Limebeer, Dr. J. C. Allwright, and Prof. D. Q. Mayne.

**Optimal Control** The different projects in this field are Algorithms for Optimal Control, Receding Horizon Control of Nonlinear Systems, Nonlinear Optimal Control Theory, Dynamic Programming. Necessary Conditions, Optimal Control of DAE Systems, and Impulse Control. The senior people of the Control Section working in these areas are mainly Prof. R. B. Vinter, and Prof. D. Q. Mayne.

**Adaptive Control & Stochastic Systems** The different projects in this field are Robust Adaptive Control of Uncertain Systems, Robust Nonlinear and Adaptive Control, Control of Piecewise-Deterministic Markov Processes, Value Information in Stochastic Control, Time Series Modeling by Approximate Stochastic Realization, Applications of Stochastic Control in Corporate Finance, The Detection and Estimation of Change in Systems, Fermentation Data Analysis, The Simulation of Conditioned Diffusions, and Analysis of Transmission Constrained Electric Power Systems. The senior people of the Control Section working in these areas are mainly Prof. D. Q. Mayne, Dr. Allwright, Prof. M. H. A. Davis, Dr. J. M. C. Clark, and Prof. R. B. Vinter.

**Industrial Systems** The different projects in this field are Direct Design Methods for Control Systems, and Fault Detection. The person mainly working in this field is Prof. G. F. Bryant.

**Microelectronic Applications** The different projects in this field are Study of Settling Time in Nuclear Calorimeters, Instrumentation and Control of Anti-Surge in Rotary Gas Compressors, Millimetre Wave Fourier Spectroscopy, Infrared Gas Analysers and Monitors, Electronic Load Governors for Small Hydro-Electric Systems, Wind Turbine Monitoring, and Physiological Monitoring. The senior people of the Instrumentation Section working in these areas are mainly Dr. J. C. Vickery, Mr. R. W. Wilde, and Dr. A. Gebbie.

For more information about the different projects listed above, see [Department of Electrical & Electronic Engineering, 1992].

## 4. Summary

The visit to Imperial College during 1992–1993 have had a great influence on me both professionally and personally. The possibility to change environment and get inspiration through contacts with other people has been very valuable for my research. The preliminary results obtained during the visit are now, as a first step, followed up in a master thesis project under my supervision. Once again I would like to express my sincere gratitude to the founds and organizations that made this trip possible. Finally, I hope that this report can inspire other to make the effort to undertake similar visits.

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