

THE ACT CLUB NEWS

Issue 18

July 2000

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- 11-15 September 2000: Hot and Cold Rolling Mill Control and Technology: International Training Courses. Strathclyde University.
- 19-22 September 1999: Predictive Control and Diagnostics for Power, Oil and Gas and Process Industries, Strathclyde University.
- 17 Oct 2000: Techniques and Applications in Aerospace and Defence, Strathclyde University, Glasgow.
- 23 Nov 2000: Non-Linear Predictive Control, Oxford University.
- Dec 2000: Intelligent Actuators and Sensors, Oxford University.
- Feb 2001: Real-time Control, Ford Motor Company, Basildon.

Welcome to the first issue of the ACT News of this Millennium! As usual we have been very busy meeting the needs of our members, including providing training courses, Case Studies and Consultancy. We have many exciting events planned for the future and these are detailed inside.

Probably one of the most exciting areas of development for the ACT Club is our Internet site. We have improved the site layout considerably and hope that this makes it even easier to use. We are just about to launch a members-only section where members (with an appropriate password) can download some of our reports, software and presentations.

Preparations for our week-long annual International Training Courses are gathering pace. These courses are targeted at engineers in industry and this year cover Hot and Cold Rolling Mill Technology and Predictive Control in the Process, Power and Oil and Gas Industries. Remember ACT Club members are entitled to free places.

This issue of the ACT News also contains two articles about Software Tools that are available for use on ACT Club Case Studies. The first looks at BEACON for generating real-time code whilst the second is on Mathematica, the symbolic manipulation package. If any Club member is interested in having a Case Study using either package then please get in touch.

I hope you enjoy the Newsletter. If you have any comments (or criticisms!) we will be delighted to hear from you.

Prof. Mike Grimble
ACT Club Director

International Training Courses

Hot and Cold Rolling Mill Control and Technology, Strathclyde University 11-15 Sept 2000

Over the last two years we have run very successful ACT Club courses on hot and cold rolling processes. The courses are intended for engineers working in steel or aluminium processing and they cover a range of control design problems on both hot and cold rolling mills. In the past these courses have attracted delegates from the United States, Canada, Japan, Australia, Europe and China. Each Club member receives two free places on these courses with additional places at half cost.

This years courses will include a mixture of basic control techniques for rolling mills and an overview of future developments. The courses will include hands on examples and tutorial sessions. They will also include contributions from some of the leading control equipment and service providers within this industry. Detailed notes will be provided and the emphasis will be on the quality and production improvements that can be obtained, rather than on the mathematics of the subject.

Details of our other new courses can be found inside. Our web-site <http://www.isc-ltd.com/training>, has complete and up-to-date information on these activities.

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Forthcoming ACT Club Events

ACT Club Session on Software Tools for Process Control, 28 July 2000

The ACT Club is organising a session on Software Tools for Process Control within the Process Control and Instrumentation 2000 Conference being organised by the Industrial Control Centre at the University of Strathclyde. The ACT Club session will be on the afternoon of the 28th July. The session aims to present some real life experiences of using modern control system design software for process control problem solving, including RapidMVC, BEACON and UNAC. This will be an ideal event to get an overview of these products and their capabilities.

The session will be open to all attendees of the Conference and is free to Club members. If a Club member wishes to attend the full day of the Conference, then there is a special rate of £60 for the day (including refreshments and a copy of the proceedings). Alternatively, ACT Club members can attend all three days of the Conference at the significantly reduced rate of £160. More details on the overall conference can be found on page 12.

Please contact Andy Clegg for details.

Introduction to ADAMS Full Simulation Package, Strathclyde University 22-24 August 2000

If you're new to mechanical system simulation, this course will give you the foundation of skills you'll need to begin using the powerful visual

prototyping, testing, and visualisation capabilities of ADAMS. This package provides the capability to integrate control engineering and mechanical engineering activities, using advanced graphical mechanical modelling.

This seminar is being jointly organised by the ACT Club and MDI being held at Strathclyde University over three days. It is split evenly between lectures and hands-on sessions. It is open to employees from all companies, however Club members get places at a discounted rate.

Techniques and Applications in Aerospace & Defence, Strathclyde University 17 Oct 2000

The recent questionnaire sent to companies revealed some interest in a special meeting concerned with the aerospace and defence industries. This event will include presentations about the techniques that are useful to this sector. For example, advanced signal processing and robust multivariable control tools will be covered followed by more specific presentations dealing with aerospace, battle tanks and naval vessels. We are calling for possible contributors to the meeting and any ideas you have on scope and content.

Non-Linear Predictive Control Meeting, Oxford University 23 Nov 2000

A very successful meeting was held at the University of Oxford in 1999 concerning advances in predictive control systems. The subject has moved on since that time with advances in the constrained optimisation algorithms and in the ability of predictive control to handle nonlinearities. This meeting at the

University of Oxford will include a mixture of these new developments and a review of basic principles. Further information on the meeting will be published later in the year

Intelligent Actuators and Sensors, Oxford University Dec 2000

This meeting is being organised by Prof. Ron Patton (Hull University) and will take place at the University of Oxford. It will describe the results of a European Union project on intelligent actuators and sensors and ACT Club members are invited to attend. The meeting should be of particular interest since it will bring together European researchers and companies at one of the research groups which is renowned for its work in this area.

ACT Club Events planned for 2001

To whet your appetite, here are some of the events we have planned for the future:

- Mathematica Training Course (late 2000)
- "Economic Justification for Control System Improvements", London Centre for Technology Transfer, Brunel University
- "Advances in Real-time Control", possibly to be held at Ford, Basildon (early 2001)
- "Intelligent Control", Strathclyde University (Summer 2001)
- "Control System Auditing Techniques" - a review of the Case Study on "Financial Benefits of Advanced Control Optimisation Packages" carried out for Marathon Oil.

Full details of all forthcoming events will be circulated to Club members 6-8 weeks prior to events taking place. Details are also being made available on our Internet Site.

Recent ACT Club Events

Training Course on Control Design for Servomechanisms, Strathclyde University 20– 23 June 2000

The number of delegates attending this course was restricted so that more individual attention could be provided to the trainees. If you missed out this time, you will be pleased to know that we are going to run it again in February 2001. Please register your interest by contacting Lorna Fleming.

18th Plenary Meeting on System Identification, Strathclyde University 11 April 2000

The ACT Club plenary meeting on system identification began with a presentation by Prof. Jan Maciejowski (Cambridge) on Sub-space Methods for System Identification. This is a relatively new approach that can be used on multivariable systems represented by state space models. The approach has been very successful in applications and seems particularly relevant for obtaining models for predictive control algorithms. Jan's talk was very well received and considerable interest was generated in the approach.

The Club was fortunate to have a presentation by Dr Zhu (Tai-Ji Controls, Netherlands). As a previous student of Prof. Lennart Ljung (Linkoping, Sweden) it is not surprising that the identification method described was an extension of predictive error identification methods. However, the presentation not only dealt with the algorithm but covered the other essential features which are necessary to have a reliable estimate

of the system models. For example assumptions regarding plant order, excitation signals and frequency domain fitting were all discussed. A very impressive commercial software package was demonstrated that has apparently been used extensively by major companies such as Dow Chemicals, BP and Air Products. At the present time the package is mainly aimed at the relatively slow process industries such as petrochemicals and Club members may obtain an evaluation licence.

21st Steering Group Meeting, Ross Priory, Loch Lomond 10 April 2000

The ACT Club Steering Committee met for the second time out at Ross Priory on the banks of Loch Lomond. This is a facility of Strathclyde University where small meetings may be held in a very convivial atmosphere. Ross Priory includes a Golf Course and extensive gardens.

All members of the ACT Club were invited to attend this meeting and it was followed by an excellent evening dinner. The steering committee is of course responsible for ensuring the ACT Club fulfils the general needs of its members.

1st Energy Special Interest Group Meeting, Marathon Oil, Aberdeen 21 March 2000

The first of the Energy, Oil and Gas Special Interest Group meetings was held at Marathon Oil's offices in Aberdeen. The meeting was chaired by David Laing who also kindly provided the hospitality. The event was so successful that there were more applications to attend than could be accommodated. The meeting included stimulating presentations from a variety of companies that have

enjoyed real benefits from the application of advanced control. Phil Fedenczuk (BP) described their success at working with Honeywell Hi-Spec in applying predictive control methods. David Laing described initiatives at Marathon to reduce costs and improve the quality of control.

A useful discussion ensued at the end of the event, debating what objectives the fledgling SIG should have

Marine SIG Meeting on Ship Roll Stabilisation, Strathclyde University 1 February 2000

The 6th Marine SIG Meeting was held at the University of Strathclyde and was concerned with Ship Roll Stabilisation Systems. The main part of the day was spent on the recent ACT Club Case Study on this subject. The requirements of the Case Study were presented by Paul Methven of the MOD and the findings presented by Dr. Reza Katebi. Some additional work on operability implications for the Control Systems had been carried out by DERA and these were presented by Paul Crossland.

The remaining presentations covered different techniques and applications in this area and included some very interesting presentations from Dr. Tony Fairlie-Clarke, Glasgow University and Peter van der Klugt, Imtec, the Netherlands. Applications were covered by George McMeel, Brown Brothers and Steve Colliss, Maritime Dynamics Inc. Overall the meeting was a great success and everyone who attended found it very useful.

Applications of Advanced Control, Cambridge University 17 November 1999

This meeting hosted at Cambridge University was intended to provide an

insight into one of the leading research groups in Europe and get an appreciation of the application work they are carrying out. Presentations covered a wide range of topics including the use of Predictive Control to provide fault tolerance and in particular an application of a ship steering mechanism was discussed. Automotive engine control was also discussed, as was robust flight control and automotive suspensions, and power applications. We also had time to have a tour of the research laboratories, seeing the impressive test facilities they have at Cambridge.

**ADAMS for Control
Systems Design,
Strathclyde University
2 November 1999**

This meeting was jointly organised by the ACT Club and Mechanical Dynamics and was intended to provide ACT Club members an opportunity to see what a mechanical systems modelling tool can do. Adams, one such tool, has the capability of directly importing data from CAD packages and constructing complex dynamic models of the system. This includes the usual inertial and rigid body dynamics, but also can include flexible bending modes and non linear elements such as friction. These are integrated into a graphical environment which can be linked with conventional control system design tools such as Matlab, Simulink. The event provided a useful introduction into the capabilities of such a system giving an insight into how mechanical engineering and control engineering tasks activities can be integrated.

If any member would like copies of the material distributed at the above meetings then please contact Lorna Fleming at the usual address.

**Monitoring and Control
of Food Manufacturing
Processes, Omron
Electronics, London.
30th Sept 1999**

This event was the first to be held by our London based sub-centre and it was held in the premises of Omron Electronics in London. The meeting provided an opportunity for researchers and innovative companies to talk about new technologies that are emerging in the food processing industry and highlighting the needs of the sector. The meeting spoke about novel sensor types and how they can be integrated into quality systems. Most of the requirements for the food industry seemed to stem from the needs of sensing and instrumentation on their processes rather than specific control problems. The meeting also enabled the academic and industrialist to talk and air their views on what would be required by a Food Special Interest Group.

**ACT Club/ICC 1999
International Courses**

Last year the ACT Club jointly with the Industrial Control Centre arranged courses in Hot and Cold Rolling Mill Control and Technology and Advanced Control for Power Generation and Distribution. Both these Courses were open to ACT Club members and also to external paying delegates and both courses were very well attended.

The Hot and Cold Rolling Mill Courses attracted delegates from Australia, Argentina, China, USA, Finland, Spain and many other countries. The combination of having parallel Hot and Cold Rolling sessions seemed to work well allowing the delegates to interchange ideas and experiences.

The Advanced Control for Power Generation and Distribution Course was very well attended by ACT Club members, attracting almost twenty delegates. This years course has been modified slightly to concentrate on Predictive Control, the one advanced control technique that has become accepted in the process industries. Hopefully this change will make the course even more useful and also widen its audience.

The ACT Club would like to thank all the companies who supported our courses in 1999. We hope to see you all again in 2000.

**International Training
Courses (cont.)**

**Predictive Control and
Diagnostics for the
Process Industries,
Strathclyde University
19–22 Sept. 2000**

This four day International training course aims at maximising the economic benefits which power, oil and gas and process companies can achieve by using predictive control techniques.

The course has three parallel themes with different modules focussing on:

- Power Generation & Transmission
- Oil and Gas Industry
- Chemical and Process Industries

The course will focus on practical engineering issues, implementation and commissioning problems and process loop tuning, rather than the mathematical aspects. Various tutorial sessions and hands-on simulation examples will be used to reinforce the learning. The course is intended for process plant control engineers, system designers and support staff.

ACT Club Member News

New ACT Club Members

During the start of this year we have had several companies join the ACT Club. Some of these have been past members. We also have some new members and we look forward to introducing them to the benefits of the ACT Club.

SmithKline Beecham have joined the ACT Club to undertake a Case Study looking into the difficulties of pH Control, including practical issues such as the sensor degradation and instrument location. The very practical nature of this Study will make it of interest to other Process and Chemical Companies.

BP Grangemouth. It is nice to welcome back BP into the Club and we look forward to working with them. Our work for BP will include Training Courses and Consultancy work.

NNC used to be members through their links with GEC Marine however company changes have forced them to become members in their own right. We are already helping NNC with advice on Modelling Tools and will be providing Training and Consultancy over the coming year.

BAE Systems (Edinburgh). Our links with BAE Systems in Edinburgh have been well established over the past two years. It is only recently that they have decided to join the ACT Club to perform a Control Design Case Study that will look at H_{∞} Design of Servomechanisms. This practical Study will take one of their existing Servo Systems and attempt to build a practical H_{∞} Control Solution and demonstrate its performance improvements.

GKN Westland - the aerospace and defence interest in the ACT Club were considerably strengthened by the participation of GKN Westland. The success this company has achieved in the military helicopter market has been well documented in the press recently. Some of the new standard courses the Club is introducing are specifically aimed at the Aerospace and Defence industries although for example that on servo mechanism control applies to many other application areas. We are pleased to welcome Westland to the Club.

Member Training Courses

All of our Club members are entitled to two days of training at their company premises free of charge. As you know we have a standard set of courses (see page 14 for full list) that are the most frequently given, and therefore have the best quality set of notes. If you want a training course simply select which course suits you, or give us a call so that we can tailor a course to meet your exact requirements. We do have many separate *training modules* available that may provide just what you want.

This year we are in the process of defining training courses for:

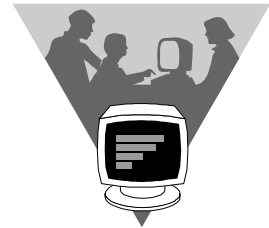
- GKN Westland** (Control and Mathematical Tools)
- Marathon Oil** (An Introduction to Process Control)
- BP/Roche** (An Introduction to Process Control)
- Air Products** (Predictive Control)

We have also been busy developing new course material and have finished the new training course on servomechanisms, which was given to Pilkington Optronics.

As described on page 3, this new course was also put on in June for all

ACT Club members. If there is sufficient interest we will host it again in February 2001 - so please let us know if this is of use.

Finally, the ACT Club, together with Wolfram Research, are going to be putting on a Training Course on the symbolic manipulation package Mathematica. This is scheduled for late 2000.



Member Consultancy

Along with all the Case Study work that the Club has undertaken recently (see page 6) the Club has also been providing a lot of short term consultancy assistance for its members. This includes validation of models, help with automation projects, advice on interfacing Matlab/Simulink with external simulation packages, advice on process plant configurations and carrying out a review of internal documents.

Over the coming months we have much consultancy work to carry out, the main one being a review of how Adams can integrate into the mechanical and control design activities at **Pilkington Optronics**. This activity will enable Pilkington to see first hand how easily Adams can integrate with their existing CAD and Control Design Tools, and to see if it offers any real benefits.

We are also providing advice for **British Energy** and **Roche Products** on various instrumentation and process control.

Current ACT Club Research Activities

Case Studies

This year the ACT Club has been exceptionally busy doing Case Studies for its Club members many of these Case Studies are now nearing completion and you should soon be inundated by Case Study Reports. Many of the Case Studies have been very useful for the companies concerned and indeed it seems to be a trend these days that companies decide upon a very specific series of tasks when they join or renew their Club membership.

The work on **Gas Turbine Fault Detection and Isolation** was carried out by Ron Patton at Hull University is now in draft form and will soon be issued to members as a Case Study Report. This Report is a very detailed analytical investigation that will be useful to any Club member wanting to apply such techniques to their equipment or processes.

Another Case Study that has been completed recently was for National Grid. This Case Study was concerned with the analysis of a multi-node interconnected power system, specifically part of the National Grid. The Study was to investigate **Prony analysis to identify stability** status of the various dynamic nodes within the transition system. Again this Report is currently in draft form and will soon be issued to Club members.

A Case Study of great interest to the Marine Special Interest Group is our Study on **Fin Roll Stabilisation Control Systems**. This consisted of a comparison between different design strategies such as H_∞ and other advanced strategies including QFT. Initial results were presented at the Marine SIG Meeting earlier this year

and a final Report including all of the analysis is due to be completed soon.

A new Case Study that was requested by Corus Group and this has now been effectively completed is on the use of **genetic algorithms for system identification**. This Case Study has been carried out to develop a practical tool that can be used for off line identification of both open and closed loop systems and with and without dead time. The benefit of using genetic algorithms is that it provides a evolutionary optimisation of all system parameters including model structure and order and process dead time, which can be difficult for traditional system identification techniques to estimate. The final Report for this Case Study is expected in August 2000. A series of Matlab m-files will also be available for Club members to try out their techniques on their own plant data.

Other ongoing and future Case Studies in the pipeline include:

- Robust Looper Control
- Hot Strip Mill Microstructure Control Review
- Financial Benefits of Advanced Control Optimisation Packages
- Servo System Modelling and Study of H_∞ Control Design
- Kalman Filters for Temperature Measurement Predictions



Advanced Control with Less Pain

We have been making rapid advances in recent months on the subject of generating low order controllers, which provide the same performance as high order designs. The subject is called Restricted Structure Controller Design and we have for example been able to tune PID Controllers to give

performance something like Advanced LQG Solutions. The main advantage should be that it will de-skill the time consuming task of tuning controllers.

Two recent advances in this area can be mentioned. The first concerns the type of models that have been employed. Up to very recently all of the work has been based on transfer function (polynomial descriptions) for systems. However, some members are more interested in using state space models. We have therefore produced a restricted structure solution for systems represented in state equation form.

Roy Nicholls (Corus) is helping to rewrite the restricted structure report for an industrial readership so that it is presented in a more accessible form. This should be available July 2000. A research report is available for those of you who cannot wait.

If there is sufficient interest from members a Matlab toolbox will be constructed to make available this advanced tuning method together with more traditional Ziegler-Nichols techniques. For further information on progress please contact Mike Grimble.

The second major advance is to extend the technique for minimising H_∞ cost functions. A report on this subject has also recently been completed.

The application chosen for the low order H_∞ design was a ship positioning system. In such cases wind feed forward is often used. The difficulty with normal LQG or H_∞ solutions is that the feed forward controllers are very high order where as in practise very simple solutions are used. The example in the report demonstrates that low order H_∞ solutions can be obtained that provide almost the same performance as the full order H_∞ solutions. There is a very impressive reduction in complexity.

Forthcoming Reports

We have many forthcoming Educational Notes and Technical Reports. The most imminent of which is the Educational Note on **Restricted Structure Controller Tuning** described above.

Another Educational Note on its way is a simple description of **Swept-Sine Frequency Testing**. This Note describes the methods used by commercially available transfer function analysers. This resulted from an enquiry from a member as to how to implement such a swept sign test in Matlab/Simulink and therefore a segment of code is provided within the Report to do exactly that.

We have several Technical Reports in the pipeline, including:

- **Survey of Signal Processing Techniques**
- **Industrial Process Control:** authored by Prof. Mike Johnson.
- **Neural Networks Applications in Marine Systems:** a very well written and informative report.
- **Problems and procedures for Multivariable process control**
- **Mathematica Applications Study**

If any ACT Club member would like additional copies of any of our reports then please get in touch at the usual address

A full list of our reports can be found at the back of this newsletter.

ACT Club Internet Site

As mentioned on the editorial of the Newsletter our ACT Club web site has been restructured and improved over the last few months. Those of you who have visited it recently should be aware of these changes and I hope they are an improvement. A new members only area of the web site

has just been established this will provide members with the ability to log and download Reports and software electronically from our web site. At present only a small percentage of our reports are available online but we will be getting more of them online as time progresses. You may also be reading this Newsletter online as we are publishing our Newsletters via this mechanism as well (although these will be freely available to non members as well). It is our intention to also make presentations given at Club meetings downloadable as well although this can obviously only happen for those that we have electronically and permission from the speakers to do so.

A letter describing the password protection system (including your password) will be sent to all Club members shortly. The password and username will be specific to an individual Club member, and so it should be passed around the entire company/site so that any employee of a company can access online deliverables. The reason the passwords are generic to a whole company is to simplify the administration of this system as it would become unwieldy to administer it for individual people.

We hope you make use of this online availability of our Reports, as we will be monitoring accesses to determine how much effort we put into this area in the future. Please feel free to let us know your comments on this initiative and its usefulness to you.

The on-line registration facility for our meetings has proved to be very popular. Thank you for using it.

Finally, for those of you who have visited our Web site over the last few months will have noticed that we now have a new (and shorter!) domain name.

This change also applies to our e-mail addresses (given on the back page). If you do forget to update your bookmarks and address book, the old pages will automatically re-direct you to our new web pages, and the old e-mail address will still get through.

Main ACT Club Page:
<http://www.isc-ltd.com/actclub.html>
ACT Club Events:
http://www.isc-ltd.com/act_event.html
Resource Centre:
http://www.isc-ltd.com/resource_centre

Software Packages in the ACT Club

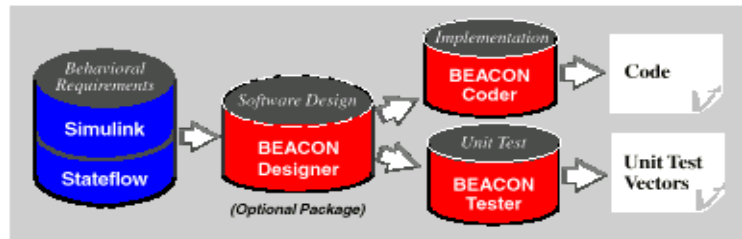
BEACON

BEACON is a software development, automatic code generator and automatic unit test tool that has been specifically designed to enable engineers to graphically specify control system designs and then to automatically generate efficient high integrity code and unit test vectors directly from the graphical design. BEACON is used by a number of US and European aerospace/ defence and process control companies and has already been used to generate code which has been certified for a number of safety critical applications; such as the GE90 engines of the Boeing 777 and high profile military aircraft projects.

Two versions of BEACON are currently available: BEACON and BEACON for Simulink.

BEACON: BEACON has been specifically designed for developing high integrity software. BEACON provides the system, control and software engineer with an integrated environment for developing embedded software. Using a combination of control flow, signal flow diagrams and data windows, users can graphically specify the complete control system. The intelligent GUI then performs verification and safety checks on designs preventing software or design errors ever reaching code.

BEACON functionality is extendible, users can create application specific libraries that can contain BEACON diagrams, legacy code, or project data. Once created a library is a reusable module/object that can then



The BEACON development package provides a seamless framework for generating and unit testing software from Simulink and Stateflow models. The generated software can be executed on a variety of platforms, including production ECUs.

be included in other BEACON diagrams.

The combination of graphical capture of specifications/designs and BEACON's documentation facilities also greatly simplifies software maintenance and reuse.

BEACON for Simulink: enables users to generate high-integrity source code and unit test cases directly from Simulink and Stateflow models. This provides a powerful and seamless environment for controls and software engineers to develop embedded control systems from idea to product and removes the need for hand translation of models between modelling and software tools. It also removes the potential for misinterpretation errors to occur as result of communication barriers between engineers of different disciplines.

Whether using BEACON or BEACON for Simulink the same Unit Test tool and code generators are used.

Code Generation: The code generated is efficient and complies with programming best practices and standards. The code is compiler-independent and can execute on host platforms, real-time stations, or embedded microcontrollers.

Languages Supported:

- ANSI-C
- Ada-83
- SPARK-83
- FORTRAN-77

Automatic unit test tool: Automatically creates unit test vectors, enhancing the quality and reusability of the design and generated software. The test vectors target common error sources such as incorrect Boolean logic, one-off comparison defects, and numerical overflows. The AUTT also provides "coverages" that are required by the strict guidelines used by the FAA.

Analysis Outputs

- Calculation of design ranges
- Notification of numerical overflow and underflow
- Identification of dead or deactivated code
- Generation of expected results
- Computation of various complexity measures

MATHEMATICA With Control System Professional

Mathematica is a so called symbolic computational package. That is, symbols are not imposed on the software through an agent or a toolbox running separately from the main code. Working with Mathematica involves a very direct approach to mathematics. With symbolic computation various of algebraic operations can be undertaken, the most exciting one perhaps being the symbolic integration.

Symbolic computation allows the scientist/programmer to better express what they are dealing with, due to the direct correspondence

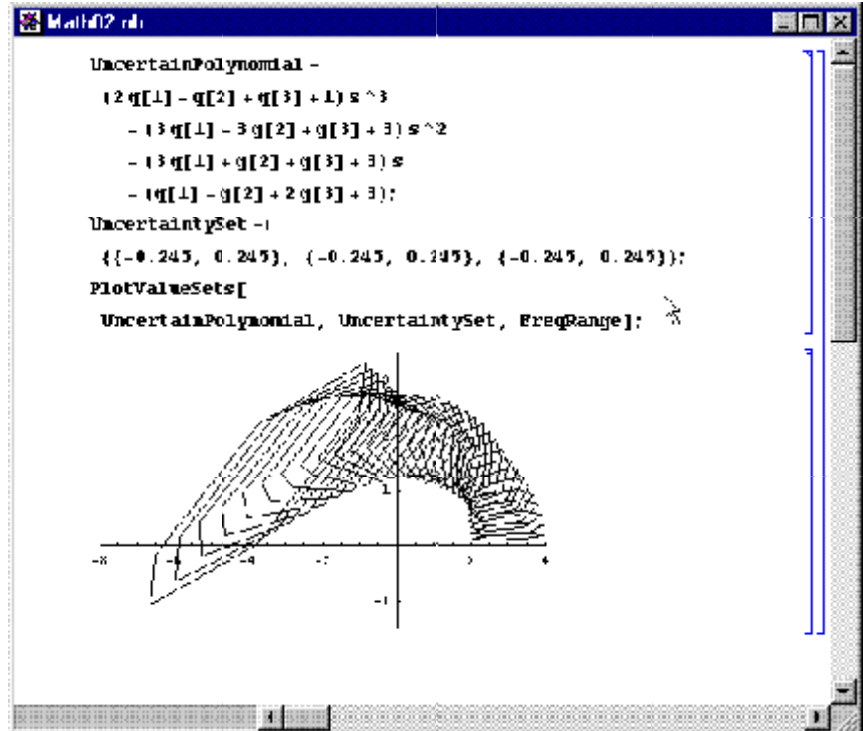
between the idea in mind and the typed lines in a Mathematica notebook. Symbolic computation also enables the user to perform otherwise impossible calculations such as those involving symbolic information only.

However, its symbolic nature does not mean that the programmer is stuck with slow computations. Numerical rather than symbolic computations, can be forced to be performed by placing any expression in brackets preceded by N (N[.]). This leads to much faster execution, but all calculations are then only at the precision of the underlying processor.

When performing calculations in many programming packages, the results are often prone to errors or may be spurious due to the finite precision. However, in Mathematica it is possible to carry out infinite precision computations. This has been found to be particularly attractive when a transfer function is required involving a connection of systems and filters. Mathematica perfectly cancels poles with matching zeros and returns the correct answer, not an answer including many extra spurious poles and zeros.

In Mathematica the programmer works on notebooks, which can be envisaged as being both a Mathematica code file and the command line. Everything typed appears on the screen, and is executed when followed by [Shift]+[Enter]. The notebook is an active environment rather like a powerful editor. It is dynamic in terms of tracking the consistency of parentheses. This becomes particularly useful when highlighting part of a complex equation. This saves time and ensures that a logically complete expression contained within a consistent set of parentheses is copied.

In Mathematica you can work on a particular topic, try out new ideas and



plot graphs, and then save the work done so far. This includes the workspace and everything seen in the notebook from the code, the output and the generated plots. This is very useful, because as soon as a previously saved notebook file is loaded, all of the previous work appears on the screen, giving a fast and clear snapshot of progress. Finally, when a piece of work proves satisfactory, the code can be converted into one general module, which then can be called from inside any other program, thanks to the modular programming property of Mathematica.

With Mathematica it is straightforward to create animated plots. This is particularly useful for animation of root loci corresponding to different gain values for a system with parametric uncertainty. This can provide a tremendous amount of insight, just by seeing how the calculated robustly stabilising gain range actually maintains the clouds of uncertain poles in the left half plane.

Unlike other mathematical computing packages, self-explanatory verbose function names are used in

Mathematica by convention. This makes it easier for the programmer to understand the code. In addition, with the aid of the powerful help function, the programmer can easily retrieve or recall functions within the context of the word/clause fed into the search.

Mathematica has the capability to export code to other formats enabling the programmer to convert a nicely written notebook into HTML format so that the results can be posted on the Internet or converted into TeX. With this power of obtaining near-documentation standard results, a TeX document can be prepared easily without having to retype all that has already been typed in the notebook.

The Control System Professional is one of the numerous packages in the Mathematica Applications Library which extend the functionality of Mathematica. The Control System Professional is an integrated set of tools which allows key aspects of control engineering to be performed. The software makes provision for modelling, design, analysis, refinement and simulation.

(continued on page 13)

CONFERENCE NEWS

Control Applications in Kona, Hawaii

The IEEE Conference on Control Applications was held in co-operation with the IEEE International Symposium on *Computer Aided Control System Design* on the Island of Kona, Hawaii. There were about 400 attendees at the Conference and most of the sessions had a distinctly industrial theme. The Conference on Control Applications has grown steadily over the years in significance and stature. On this occasion a significant proportion of the delegates attended from Japan. In fact, one of the co-sponsors of the Conference was the Society of Instrumentation and Control Engineers, Japan. It was unfortunate there were rather more *no shows* than usual. Nevertheless, the meeting attracted some excellent contributions and interesting sessions.

Prof. Hidenori Kimura (University of Tokyo) presented one of the outstanding papers at the event. His plenary presentation was *Uncertainty, Complexity and Learning: A Control Perspective*. He posed a number of questions from a user point of view:

1. Which control method is appropriate for the problem in front of me?
2. What is the intrinsic limitation of the design method chosen?
3. What is the benefit of a complex architecture for controllers in comparison with simpler ones?

He believed that these questions are mostly unanswered in control theory, which is algorithm orientated.

To illustrate Prof. Kimura's talk he used simple examples and focused on the simultaneous stabilisation problem. This is the problem of using

one controller to simultaneously stabilise two (or more) very different system descriptions. One of the problems considered is whether there would exist a simultaneously stabilising solution. He gave an example of two unstable plants with the same poles but where it was impossible to find a single stabilising controller for both of the plant models. The presentation did not conclude with an answer to all the questions posed but by considering the simultaneous stabilisation examples a greater understanding was provided of the effects of the uncertainty and a different perspective was obtained on the robust control design problem.

Prof. Stephen Boyd (Stanford University) also gave an excellent plenary presentation on *Optimisation Over Linear Matrix Inequalities*. He was able to demonstrate that many real applications can be solved by this approach not only in control theory but in subjects such as:

- Combinatorial Optimisation and Graph Theory
- Structural Optimisation
- Statistics
- Signal Processing
- Circuit Design
- Geometric Problems.

Linear matrix inequalities solve non-linear convex optimisation problems that are tractable in both theory and practice. They may be solved efficiently using a variety of techniques and there are also very interesting duality results. However, the main point of his talk was to illustrate that these occur in all branches of engineering and science and once a problem has been reduced to this form it may be solved very easily by existing techniques. His examples included a VLSI wire and transistor sizing problem and a static optimisation problem involving

mechanical engineering and truss design. This exemplary plenary was presented in a very tutorial style and it demonstrated the relevance of these techniques to many different fields.

Prof. Mike Safonov (University of Southern California) introduced the relatively new topic of *Unfalsified Control Theory* in two papers. This might be considered a new approach at control, which relies on plant data rather than models. His first paper considered *Selection of PID Controller Gains by Only Using Observed Data*. Prof. Safonov noted that unfalsification can be considered another word for validation. He also explained that unfalsified control is a precise formulation of the controller validation problem in a hypothesis testing framework. Controller validation completed in real-time leads to a form of adaptive control algorithm. He was able to show how the general framework also enabled system identification problems to be considered from a similar viewpoint.

A special session was organised on metal processing and there was particular interest in the paper by Kirayama (Nippon Steel Corporation) on *Looperless Rolling in Hot Rolling Processes*. There was also interest in the paper by Kadoya (Sumitomo Metal Industries) on *Thickness Control in Tandem Cold Mills*. The so called *Inverse Linear Quadratic Design Approach* was used by these authors with some success.

There was also considerable interest in a session on *Flight Control Systems and Gas Turbine Control* and Stephen Yurkovich (President of the IEEE Control Systems Society) described work on *Bayesian Belief Networks for Fault Identification*. A popular session on *Fault Detection and Diagnosis* was also held and George Fodor (ABB) considered the *Use of Object/Unified*

Modelling Languages in Fault Detection Problems. Chen (Rockwell) discussed *Component Base Modelling and Diagnosis of Process Control Systems*. There was quite a lot of interest in the session of PID control with an interesting paper by Panagopoulos (Lund Institute of Technology) that employed H_∞ Loop Shaping Ideas for PID Controller Design. This was unfortunately one of the sessions that was desimated by no shows.

A very interesting session was also held on *Ship Motions and Offshore Structures*. Thor Fossen (University of Trondheim) presented their work on *Dynamically Positioned Vessels* that also use thruster assisted mooring systems. His talk was reinforced by a second contribution from Jann Peter Strand (ABB Industries) on *Thruster Assisted Positioned Mooring Systems for Turret Anchored Vessels*. Ikuo Yamamoto (Mitsubishi Heavy Industries) described the use of *Linear Matrix Inequality Methods for the Design of Dynamic Ship Positioning Systems* and his contribution was in fact applicable to other industrial problems. *Underwater Vehicle Control* was considered by Boskovic (University of California, San Diego) and the *Control of Electro Statically Suspended Gyroscopes* was considered by Alex Fax (Californian Institute of Technology). The aim of his technique was to reduce calibration time providing faster prototyping and reduced costs. These systems are apparently used in submarines and the work is in co-operation with Boeing. A rather important paper relevant to the marine environment was by Masanori Ito (Tokyo University of Mercantile Marine) on *Collision Avoidance Using Genetic Algorithms*.

One of the rather unusual sessions was concerned with *Evolutionary Computing in Control Engineering*. New software tools and approaches for control systems design were represented in two papers by Yun Li of

the University of Glasgow. He discussed the use of *Genetic Algorithms in Computer Automated Design of QFT Control Systems*. It was well known that quantitative feedback theory can be a little awkward to use and his talk described a valuable tool to assist this process.



European Control Goes from Strength to Strength

The European Control Conference is held under the auspices of the European Union Control Association and the conference has now become one of the leading European forums for control theory and applications. Contributions were received from over seventy countries which reflects the strong international interest in this meeting. The official opening session was followed by a plenary talk by Prof. Karl Johan Åström (Lund Institute of Technology, Sweden).

The plenary talk by Prof. Åström was entitled *Automatic Control - The Hidden Technology* and this was the highlight of the conference. Åström noted that automatic control is about fifty years old and when it was introduced it represented a paradigm shift from the traditional split of engineering disciplines into civil, mechanical, electrical and chemical engineering. He noted that automatic control systems are pervasive in just about every field of life ranging from automotive products to so-called white goods (washing machines, fridges etc). His contention was that automatic control is the first of the systems disciplines that transcends the boundaries of the traditional engineering fields. Since automatic

control can be classed as a major systems engineering discipline, Åström believed that the subject should take on full responsibility, by educating students that are capable of solving the whole problem from conceptual design to implementation and commissioning. He pointed to complex systems as being one of the major challenges for the future. He noted that the emerging field of hybrid systems is one attempt to deal with complex processes that involve mixed logic, sequencing and continuous control. It is a subject which provides an interesting meeting place between the disciplines of control engineering and computer science.

This presentation by Karl Åström was all the more poignant since it followed on very shortly from his retirement dinner held in Lund. However, there is little chance that this will be the last presentation that Karl makes to our field, since he remains the most influential ambassador for control engineering and one of the most original researchers in the subject.

Prof. Mogens Blanke, (Aalborg), gave one of the plenary presentations on the subject of fault tolerant control. He noted that system availability was often a driving factor for both safety and economy. A large proportion of plant close-downs are accidents that can be avoided if faults are prevented from developing into failures. Unfortunately control systems themselves can amplify or hide faults until complete break down occurs. The objective of his presentation was to provide a method, which would ensure plant availability, by accepting a reduced performance when faults arise, rather than complete failure. Blanke noted that *robust control design* can cope with uncertainty in normal operation and *fault tolerant design* can cope with fault conditions. His aim was to obtain a compromise between good performance and plant availability. Thus, some sacrifice of performance might be warranted if

this enables higher plant availability to be guaranteed. He also introduced the topic of fault propagation analysis which reveals where faults can be stopped from developing into failures. He described *severity analysis* that determines which faults are the most important. He provided two very impressive industrial applications to demonstrate the concepts. The first was a diesel engine and CP propeller used in ship propulsion systems. The second was the Danish OERSTED satellite that uses fault tolerant attitude control systems. His contention was that *fault tolerant control was the next revolution in control engineering* and we are only beginning to recognise the importance of this area.

One of the more unusual sessions at the conference was a European Commission Information Session. This was presented by Mr. H. Pero and was entitled the Fifth Framework Programme of the European Commission and related International Initiatives. Mr. Pero represented the European Commission's Director General XII (Science and R&D). He overviewed the latest European Union support initiatives and indicated the shift towards technology transfer and assessment activities. There are still opportunities for original blue skies research projects, but in the main the new programmes are to assist companies to adopt recent technological advances.

A number of conference sessions were sponsored or prompted by European Union research projects. A session on the *applications of polynomial system design methods* was organised by Vladimir Kucera and Michael Sebek (Academy of Sciences of the Czech Republic) based on the EUROPOLY research project. The application of polynomial H_∞ controller design for *mussel moment control* was described by Peter Jaime (Glasgow University) and the use of polynomial techniques in fault

diagnosis was considered by Eric Frisk (Linköping University). The use of Fast Fourier Transforms in polynomial system algorithms was discussed by Martin Hromcik. Michael Sebek provided an excellent overview of the new control system design tool, PolyX. This is a MATLAB based polynomial systems toolbox that is available commercially. There is also increasing interest in Symbolic Manipulation Languages for all aspects of control systems synthesis and design. Prof. Neil Munro (UMIST) presented an overview of this type of software using the package *Mathematica*. Such tools have very different properties to the MATLAB based numerical packages and can provide *infinite precision*.

Dumitriu (University of Karlsruhe) discussed the design, implementation and commissioning of a fuzzy adaptive mould level control system for steel making. There appeared to be considerable interest in this development and there appears to be a range of applications of the new approach.

The European Control Conference is now established as a major international event with an attendance which matches any of the US based leading conferences (around 1,000 delegates). Karlsruhe is in the centre of an industrial region, but the City was very pleasant indeed and the Conference Centre was centrally located with numerous local hotels at reasonable cost. It was therefore one of the most suitable and successful events and Prof. Paul Frank (Duisburg), who acted as the General Chairman, is to be congratulated.

The Conference has a two yearly cycle and the next will be held during 4-7th September, 2001 in Porto, Portugal. The first announcement and call for papers is already available on <http://www.fe.up.pt/~ECC 2001>.

Process Control and Instrumentation 2000

The Institute of Measurement and Control are to introduce a new series of conferences focusing on process control. The first such conference, **Process Control and Instrumentation 2000**, will be held at the University of Strathclyde on 24-26th July, 2000. Many control-engineering conferences tend to be rather theoretical but this particular event will concentrate on the practical issues of instrumentation systems, advanced and classical control, system simulation and modelling and plant identification.

A new innovation at this conference is the introduction of specialised tutorial workshops, focussing on particular industrial topics or introducing new technologies. If you or your company would like to be involved in one of these self-contained events then please contact Prof. Mike Grimble or Prof. Mike Johnson. The Conference web-site can be found at:

<http://www.icc.strath.ac.uk/events/indexa.htm>



What's in the Next Issue of ACT News

Over the next few issues of the ACT News we intend to publish a series of articles produced by Prof. Dennis Bernstein of the Aerospace Engineering Department at the University of Michigan.

The first of these will be "A students Guide to Classical Control" which is an excellent non-technical article to all engineers about the fundamental lessons in control that we all should remember.

Software Packages in the ACT Club (cont.)

Discrete and continuous-time systems, time and frequency domain analysis, as well as scalar and multivariable systems are all features of the package. Systems can be composed of blocks using a number of interconnection techniques. In addition time delay systems can be handled and a library of linearisation methods is provided for non-linear systems.

Control tools within Mathematica give the advantage that symbolic and numeric models can be used together providing greater analytic insight. The arbitrary precision provided removes concern over numerical error which may be a factor in other computing environments. An object orientated approach is taken to simplify the manipulation of control system components.

You can obtain a flavour of Mathematica's power of computation by going to the dedicated site www.integrals.com which is hosted by Wolfram, the developer of Mathematica (www.wolfram.com).

A demonstration of Mathematica will be given on 28 July (see page 2) and a training course will follow in late 2000.

Next Generation



For those of you who do not know, our Secretary Lorna Fleming has been away on maternity leave. On the 21st February 2000 she gave birth to a lovely baby girl called Amy. Both mother and baby are very well. I am sure everybody associated with the ACT Club will join us in wishing both Lorna and baby Amy all the best.



Industrial Control Centre News

ACT Supports University Initiatives

The Advanced Control Technology Club based at the University of Strathclyde in Glasgow has recently provided support for two university research initiatives that have been awarded by the Engineering and Physical Sciences Research Council. The first is a Marine Network that will bring together ten of the leading University Marine Research Groups with ten international companies involved in this area. The aim of this network is to stimulate research and development activities in the use of advanced control systems in marine applications. This will cover all aspects of marine systems from motion control systems to power control and monitoring. New applications such as all-electric ships or high speed ships will feature in the network, as will new technological advances including system identification and signal processing.

The second project involves co-operation between the University of Oxford (Dr Basil Kouvratakis and Dr Mike Cannon) and the University of Strathclyde (Prof. Mike J. Grimble and Dr Andrzej Ordys). This project is focussed on non-linear constrained predictive control, with its aim being to improve industrial predictive control algorithms so that they are applicable to a wider class of system. Applications are being considered in the metal processing and power generation and transmission industries.

Book Review

Title: Fuzzy Theory Systems : Techniques and Applications
Publisher: Academic Press
Editor: Cornelius T. Leondes
Publication Date: 1999

The edited volume by Cornelius Leondes on **Fuzzy Theory Systems : Techniques and Applications** is an extremely comprehensive four volume set, which covers all aspects of fuzzy system modelling and control. The contributions are from many of the leading researchers in the subject and cover modelling, system identification, signal processing, control design and applications. The Foreword is provided by Prof. Lotfi A. Zadeh who states that it is a wide ranging collection of authoritative and up-to-date expositions of fuzzy set theory and its applications, and who would argue with such a distinguished researcher in this topic.

The text provides one of the most comprehensive and up-to-date overviews of the topic and it should be of interest to both control theorists and engineers in industry. Indeed, many of the papers are illustrated with industrial problems and many of the topics are very relevant to engineers in industry. For example, intelligent PID controllers are discussed and even the combination of H_∞ and fuzzy techniques is considered. The level of these texts also makes them suitable for use on senior graduate level courses and the contributors are some of the leading researchers in the subject. The range of industrial topics covered includes chemical plant problems to robotics. Topics such as data based management systems and self-organising fuzzy controllers are also considered. To summarise this is a series, which is very desirable for anyone involved with fuzzy modelling, control and signal processing.

ACT CLUB TRAINING COURSES



The training courses described below are standard courses available through your company's membership of the ACT Club. The courses can be focused on your specific needs and applications and individual modules from different courses can be mixed to form a client specific course. In addition the courses can be aimed at technician to research engineer level.

Should your company require course modules which are not listed then our relationship with Strathclyde University can be exploited to ensure that tuition on virtually any control technique can be provided. Courses are generally run as and when required and can be conducted on your own premises or here in Glasgow.

All of our courses are eligible for CPD (Continuing Professional Development) as recognised by the major Engineering Institutes.

Course 1: Classical Control and PID Tuning Methods (1 Day)

The course covers basic concepts of classical control and provides practical guidelines in implementation and tuning of PID controllers. The course is aimed at technician level.

Course 2: Predictive Control (1 Day)

The course provides overview of Predictive Control techniques and

then gives guidelines for analysis and tuning of predictive controllers.

Course 3: Control Theory Fundamentals (2 Days)

The course provides training on an engineering level in Classical Control Theory and Control System Design. The course presents frequency and time domain analysis of linear control systems. The PID controller and tuning methods are also covered.

This is the **most popular** training course that we offer. It is especially useful to those engineers who may not have had specific theory teaching during their electrical or mechanical engineering degrees. It also provides an excellent refresher course in basic control engineering for practising engineers.

Course 4: Overview of Modern Control Design Techniques (2 Days)

The course provides an overview of modern control design techniques ranging from Robust (H_∞) to Predictive Control, Adaptive Control and Fuzzy Logic Control.

Course 5: MATRIX_x (3 Days)

This is a basic training course for control design and simulation using the MATRIX_x family of analysis, simulation and realisation tools. This results orientated course provides knowledge and skills that can be applied immediately.

Course 6: Control Fundamentals for Engineers (6 Days)

The course starts from basic concepts of signals, systems and computer simulation. The course covers Classical Control Systems Design Methods, PID control, Multivariable Control design, Robust Control techniques, Adaptive Control, Predictive Control and Optimal Control. The course is focused on use of advanced computer tools to control system design and simulation. The theoretical material is supported with numerous tutorial examples in MATRIX_x.

Course 7: Kalman Filtering (1 Day)

This course gives a detailed description of Kalman Filter theory and implementation.

Course 8: System Identification and Self-tuning control (1 Day)

This course presents methods for System Identification and design of Self-tuning Controllers.

Course 9: Robust Controller Design (2 Days)

The basic concepts of robustness of control system are introduced. Those are analysed using classical design methods (for both single-input single-output systems and multivariable systems) and compared with modern (H_∞) approach. Available computer design packages are discussed.

ACT CLUB SERVICES TO MEMBERS

The ACT Club provides its members with access to a very wide range of control technologies. This is accomplished through the various services that are listed below and which are **FREE** to members of the ACT Club.

- Regular Plenary meetings, training courses and awareness days on both basic and advanced subjects. *Typically 2-3 per annum, held centrally.*
- An annual training course at the company premises. This can be selected from our standard range covering virtually all topics in control, or tailored to meet your exact requirements. *Typically 1-2 days duration.*
- Case Studies proposed by members are undertaken to investigate the usefulness of new technologies. *Typically 3-4 case studies are undertaken per annum.*
- Special Interest Groups (SIGs) that focus our efforts onto particular sectors of industry. *Typically 1-2 meetings per annum.*
- Annual visits to provide consultancy advice at company premises.
- Instant access to consultants is available over the telephone, fax or email.
- The ACT Club's own range of user-friendly software packages and toolboxes designed to make advanced control more accessible.
- Access to commercial software and hardware rapid prototyping systems.
- Detailed technical reports and easy to understand educational notes.
- Regular conference reports from most of the major events worldwide on latest technology and results.
- Regular mailings and newsletters.

Case Studies

Case Studies investigate the applicability of advanced control technologies to specific industrial problems as proposed by the ACT Club members. These studies usually take the form of a 1-3 month study, which can be either simulation based or use real hardware to interface directly to the members' plant.

The following Case Studies have been carried out and the associated reports can be made available to Club members.

ROLLS ROYCE: Control of a Gas Turbine Engine (CS01/1992)

BRITISH GAS: Self-Tuning Control of a Furnace Temperature (CS02/1992)

BRITISH AEROSPACE: Pitch Control of a Generic Canard Delta Aircraft (CS03/1992)

BRITISH STEEL: Control of Reheat Furnace (CS04/1993)

BRITISH STEEL: Gauge Control for Cold Rolling (CS05/1993)

ROCHE PRODUCTS: Non-linear Model Based Control for pH (CS06/1993)

MARINE SIG: Design of Robust Ship Positioning Systems and Advantages of Feedforward/ Feedback Control (CS07/1995)

BRITISH AEROSPACE: Classical versus Modern Control Design Methods for Safety Critical Control Engineering Practice (CS08/1995)

BRITISH STEEL: Multivariable Decoupling Control of Collector Main Pressure on Coke Ovens (CS09/1995)

ROCHE PRODUCTS: Roche Vitamin C Modelling Report (CS10/1995)

BRITISH GAS: British Gas Maintenance Reduction (CS11/1996)

BRITISH PETROLEUM: Introduction to Predictive Control with Application to a Hydrogen Reformer (CS12/1996)

T&N TECHNOLOGY: Gauge Control of Cold Rolling Mill (CS13/1996)

ROYAL ORDNANCE: An Operational Planning Tool for the Royal Ordnance Nitro-Cellulose Process (CS14/1995)

BARR & STROUD: Control of a High Resolution Laser Scanner (CS15/1996)

MARINE SIG: Implementation Problems and Design of Ship Autopilots (CS16/1996)

MARINE SIG: Advanced and Classical Control of Non-linear Ship Positioning Systems (CS17/1996)

ROYAL ORDNANCE: Expert System Based Training Simulator: Picrite Process Application (CS18/1997)

UNILEVER RESEARCH: Supply Chain Management Into The Year 2000 (CS19/1998)

Technical Reports

Technical Reports provide a detailed theoretical description of specific advanced control techniques. These notes are written to be a concise and complete source of information that any engineer working in that particular field will find invaluable.

The following list gives all the ACT Club Technical Reports:

Application of Expert Systems in Industrial control (ACT Report 1/1990)

A Tutorial of Polynomial LQG/ H_∞ Optimal Control for Industrial Users (ACT Report 2/1990)

A Tutorial of Digital LQG and H_∞ Self-Tuning Control for Industrial Applications (ACT Report 3/1990)

μ -Analysis and Synthesis (An overview of an Optimisation Based Method for Multivariable Control Design) (ACT Club Report 4/1990)

Weighting Functions in H_∞ Control (ACT Report 5/1991)

Introduction to Non-linear Self Tuning Control (ACT Report 6/1992)

An Introduction to the Control of Non-linear Processes (ACT Report 7/1993)

Mathematical Notations and Glossary (TR07/1993)

On the Performance of Generic Model Control (TR09/1993)

An introduction to Neural Networks (TR10/1994)

Long Range Predictive Control: A Review (TR11/1994)

Introduction to the Benefits of Controller with Several Degrees of Freedom and the Use of Feedforward Control (TR12/1995)

Applications of Fuzzy Logic Control (TR13/1995)

Tutorial Introduction to I_1 Analysis and Synthesis (TR14/1996)

Comparison of the Design of a Marine Autopilot using H_∞ Design and Quantitative Feedback Theory (TR15/1997)

Advances in Autotune Methods (TR16/1998)

Fibre Optics and their use in Field Trials Measurements Systems (TR17/1999)

Educational Notes

Educational Notes are a simple introduction to the various control subject areas that are becoming increasingly prominent and relevant to industry. These introductory texts are aimed at engineers with no prior knowledge of the subject described and provide a basic understanding of the techniques involved.

The following list gives all the ACT Club Educational Notes:

What is H_∞ Optimal Control ? (EN01/1990)

What is Robustness ? (EN02/1990)

Typical Robust Control Design Problems ? (EN03/1990)

What is Self-Tuning Control ? (EN04/1990)

A Note on Smith Predictor for the Control Process Plants with

Significant Transport Delays (EN05/1993)

Tutorial on Variable Structure Control for Industrial Users (EN06/1995)

Simple Introduction to Kalman Filtering (EN07/1996)

An Introduction to Discrete Event Simulation (EN08/1997)

Mathematica and the Control System Professional (EN09/1998)

Tutorial Introduction to Quantitative Feedback Theory (EN10/1998)

ACT Club Software

The software packages listed below provide intuitive user friendly tools for many of the common control design laws. Comprehensive manuals and examples are provided and complementary training courses often exists.

H_∞ Robust Control Toolbox for MATLAB

Robust H_2 Feedback/Feedforward Control Design Toolbox for MATLAB (Polynomial Approach)

Multivariable Robust Control Toolbox for MATLAB

Self-Tuning Control Software

Nonlinear Self-Tuning Control Software

EASY_KIT Toolbox for MATLAB

4 DoF Non-linear Ship Modelling Package for MATRIXx

6 DoF Marine Vehicles Simulation and Control Package for Matlab

Model-Based Predictive Control Toolbox for Matlab/Simulink

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