THE ACT CLUB NEWS

Issue 13 **May 1997**

Inside This Issue:

Forthcoming Events for ACT Club Members

15th ACT Club Plenary Meeting

The next ACT Club Plenary Meeting will be held on the **25th June 1997** at Strathclyde University, Glasgow and the theme of the meeting will be "*Advances in Process Control*".

Invited speakers will come from both academia and industry and will describe their own experiences using advanced process control. Future trends and what can be expected from new technologies will also be described. An agenda and reply form is enclosed with this newsletter. Please circulate this to any colleagues who may be interested. Note that the deadline for replies is 11th June.

The UNAC real time control system design and rapid prototyping tool will be demonstrated. An alarm handling system utilising an expert system, developed as part of an ACT Club Case Study will also be shown.

A report on current and future development within the ACT Club will be given by the Club's Technical Director, Professor Mike Grimble A brief report on the management of the Club will also be made by the Steering Committee Chairman, Dr. Mel Hague.

Steering Group Meeting

A Steering Group meeting will be held to coincide with the plenary meeting. Details of the meeting will be passed to Steering Committee members with this newsletter.

Marine Special Interest Group Meeting

The Marine Special Interest Group will be holding its next meeting on the **3rd September 1997** to discuss suitable ways to progress. This will probably look at a specific application for a fault tolerant control system which will form the basis of a Case Study. More about this meeting closer to the date.

See Inside for News of More ACT Club Events

New Man at the Helm of ISC Ltd.

ISC Limited has appointed a new Managing Director, Andy Buchanan to build a business for the future and to provide a professional business environment for the ACT Club. The Club is managed by ISC which was established by the University of Strathclyde in 1986.

Club members will have become very familiar with Mr Jim Hamilton who has recently retired as the Managing Director of ISC. Andy Buchanan, who has now assumed this role, joins us from HSDE Limited and he has an excellent record of developing business strategies and changing organisational structures to meet the emerging needs of the market place. In fact he has considerable experience having previously worked as the managing director for Banchory Instruments Limited (a subsidiary of Electro-Watt), for Harland Bauteil, ABB Process Automation Limited, Accuray, Burroughs Machines and Ferranti.

Andy has also had experience in working in Switzerland, Greece and the USA and he has a strong interest in sales and marketing activities for building small to medium sized enterprises. Andy's doctrine for the future is that the *ACT Club must provide value for its members*. He will be meeting Club members over the next few months and will be happy to accept invitations to visit your company.

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Focus on New ACT Club Members

Scottish Hydro-Electric

The interest in power systems is strengthened within the ACT Club by the recent move by Scottish Hydro-Electric to join the Club. The company is responsible for Hydraulic Power generation within Scotland and is particularly interested in the training and awareness programmes the Club offers. We warmly welcome them to the ACT Club.

Toshiba International

We are pleased to welcome our most recent ACT Club member who has a very wide range of industrial interests and a reputation for using the latest technological advances.

ACT Club Meeting on "Fault Monitoring, Diagnosis and Control"

The ACT Club meeting on "*Fault Monitoring, Diagnosis and Control*", held at the University of York on the 22nd April, was a very well attended Workshop. This was primarily due to the direct relevance of this subject area to the activities of many of the Club members.

Over the last five years considerable progress has been made in the development of systems that give an early indication of fault conditions and that can isolate the source of faults, due to either catastrophic failures or a gradual degradation of sensors and actuators.

Strathclyde has been interested in the development of *combined control and fault estimation methods*. For such cases not only is a control signal produced, but also an estimate of the fault related signals. Once the fault condition becomes serious, warnings are then given and either automatic or manual intervention can be carried out.

The ACT Club's current and future research programme has substantial components of Fault Tolerant Control and Fault Monitoring and Diagnosis. This Workshop was a necessary precursor to this programme as it introduced some of the basic ideas in the design of such systems.

The distinguished speakers included *Professor Ron Patton* who opened the Workshop by asking (and answering) the question "Where are we in Fault Tolerant Control ?" *Professor Mogens Blanke* from the University of Aalborg in Denmark is another renowned contributor in this field and described a ship propulsion application. *Professor David Williams* presented a relevant look at the use of neural networks to detect and diagnose faults in industrial processes. *Steve Daley* (GEC Alsthom) presented an application of this technology to induction motor control and brought along a working test-bed to demonstrate the ideas. Finally, *David Ward* (MIRA) described a procedure to automate Failure Mode and Effects Analysis (FMEA).

Since the terminology and the techniques are new to many Club members we will be producing a tutorial report that introduces the basic ideas and notations. This report will be issued before the end of 1997. Further, co-operative projects with Professor Ron Patton at Hull and Professor Mogens Blanke at Aalborg are currently being discussed.

Copies of the Workshop proceedings can be obtained free of charge to any ACT Club member. Please contact Andy Clegg if you would like to receive them.

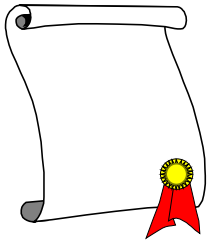
ACT Club Training Courses

Training Courses have been carried out for Rolls Royce Industrial Controls (Gateshead), Vickers Defence Systems (Leeds) and Marathon Oil (Aberdeen).

Both Rolls Royce and Vickers Defence requested the two day Control Theory Fundamentals course which 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 the ACT Club offers and is especially useful to those engineers who may not have had specific control theory teaching during their electrical or mechanical engineering degrees. It also provides an excellent refresher course in basic control engineering for practising engineers.

The training course for Marathon Oil covered classical control theory and an introduction to modern control design techniques. Demonstrations and hands-on tutorials reinforced the theory taught over the two days.

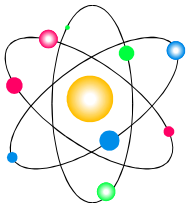


Future Initiatives by the ACT Club

Power/Energy Special Interest Group

We are currently canvassing opinion as to whether a power and energy special interest group would be of value to certain Club members. About two years ago a very successful meeting was held at Scottish Nuclear and a similar event is currently being planned.

Possible contributors to the meeting should contact Andy Clegg or Mike Grimble, or send in a brief abstract of their talk. This would provide an opportunity to discuss whether such an interest group is needed and determine its scope and the areas of mutual interest.



Workshop on Metal Processing

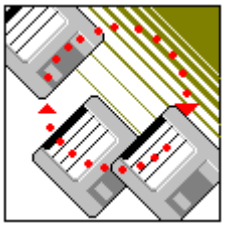
There appears to be some interest in holding a one day event for companies interested in metal rolling processes and metal processing lines. We are aiming to put together such a workshop early next year. About half of the meeting will involve an overview of new technology for metal processing and about half will deal with companies existing experience either in commissioning or in utilising such systems.

If you would like to make a contribution to this event please contact Mike Grimble by fax or e-mail. At the present time only tentative titles for talks are needed.

Improved ACT Club Software

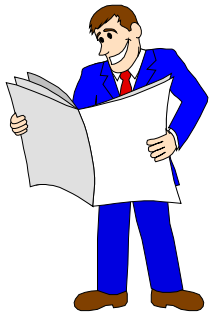
The ACT Club's policy of continual refinement of existing software packages will be applied to the linear and non-linear self-tuning toolboxes.

Enhancements of the existing toolboxes will include more robust and practical identification algorithms. The toolbox will also be converted to work with Matlab, rather than as a stand-alone package as is the case at present.



Please see Pages 7 and 8 of this Newsletter for the complete list of all *ACT Club deliverables*, including case study reports, technical reports, educational notes and ACT Club software packages.

New ACT Club Reports on the Horizon



The following is a list of ACT Club reports that are in various stages of completion :

- Tutorial Report on Long Range Predictive Control, developed by Mads Etel, Aalborg, Denmark.
- Educational Note on Quantitative Feedback Theory (QFT).
- Technical Report on Quantitative Feedback Theory (QFT), including industrial examples.
- Technical Report on Genetic Algorithms for Choosing Weights in Optimal Control Problems, by Dr Desio Dohna and Dr Reza Katebi.
- Tutorial report on Fault Monitoring, Diagnosis and Control.
- Study of Advanced Control Systems in the Workplace
- Technical report on a New Approach to Fuzzy Controller Classification
- Tutorial Report on Data Mining.

Briefings on Advanced Control Technologies

Simpler and Better Multivariable Control

Over the last decade companies have accepted the importance of robust multivariable control methods. H_∞ robust multivariable design has emerged as a major contender but there is little experience with this technique outside the aerospace and marine sectors. However it is also gradually gaining acceptability for high speed machinery control systems. There still remains some resistance to its application in the more general process industries where predictive control methods are well entrenched. One of the difficulties with H_∞ design has been the rather abstract mathematical basis for the design phase, even though the software only requires pragmatic engineering experience.

Quantitative Feedback Theory (QFT) has recently emerged as a major contender for robust control applications. Again, the aerospace industry has been the first to exploit this new design technique.

Quantitative Feedback Theory (QFT) does not rely on abstract theory and utilises tools that are familiar, such as Nichols and Bode frequency response diagrams. Up until very recently the multivariable capabilities of this approach were rather limited and the software restricted. However, the Industrial Control Centre has a co-operative project with British Aerospace and the US Airforce Institute of Technology at Dayton, Ohio, to improve the multivariable software. Staff at the Wright Patterson Airforce Base developed the initial software which is now being rewritten to form a more generic package.

Initial feedback from ACT Club members suggest some interest in QFT, in terms of training courses and tutorial reports. Therefore, the intention is to produce a short briefing note for managers and a more detailed design study report which will be made available later in the year. The training course still has to be arranged but we are hoping to have Professor Dino Houpis visit the UK as an invited speaker.

Please contact Mike Grimble or Andy Clegg if you would like further information

Can Adaptive Controllers be Made More Reliable?

Self-tuning controllers have only been applied in a limited number of industries, mainly because of their inherent unpredictability. There are of course notable exceptions and commercial products are available which are used in process industries. However, for systems which are difficult to control, such as machine control systems, adaptive controllers have not found wide acceptance.

One approach to reduce the uncertainty associated with adaptive controllers is to limit their range of adaptation. The Industrial Control Centre has recently completed a project with ASEA Brown Bovery, Red Electrica in Spain and ENEL in Italy which represent the major power generation and distribution authorities in Spain and Italy. The automatic voltage regulator developed involved a multi-loop system which had to be both robust and reliable. Voltage feedback is necessary but the stability of the overall system can be enhanced by using both speed (or frequency) and power feedback. A full multivariable self-tuning controller would be unfeasible for this system. The resulting design only altered the gains in the speed and power feedback loops. The resulting closed-loop poles were restricted to certain regions of the complex plane. This means that minimum damping factors could be specified and the degree of complexity of the controller limited.

Experience with this rather successful application led to the development of the philosophy of *limited (or restricted) authority adaptive control*.

Many other scenarios are of course possible where only part of the controller structure is allowed to vary. The benefits are clear in reducing problems with commissioning, limiting the computational complexity and in restricting the range of operation so that behaviour is more predictable.

This is a new subject and the first tentative steps have been made in categorising the different possibilities. A plenary paper on this subject presented at the IFAC Conference on Industrial Control in Belfort, France, April 1997 is available from Mike Grimble. Further details of the power system application may be obtained from Dr Michael Johnson of the ICC.

Can Genetic Algorithms be Used for Control Design?

One of the main problems in utilising optimal control methods is the choice of cost-function weightings. The weights are the tuning variables which must be selected to obtain an appropriate design. Recently it has been demonstrated that *genetic algorithms* have a role in cost-function weighting selection.

Briefings on Advanced Control Technologies (cont.)

The research is based in the ICC and the ACT Club would welcome any industrial interest. A report is in the final stages of preparation which will be issued to Club members shortly. This will include a marine design example to illustrate the technique.

"Getting the Best Out of PID in Machine Control" IEE Colloquium, London, 24th October 96.

Though the title of this Colloquium (organised by PG16, Machine Systems Engineering Applications) refers to machine control, the five papers presented were not application specific and thus of relevance to all who use PID controllers. The papers covered topics such as the Relay Auto-tuning methods for PID controllers, selection of appropriate PID Controller structure, the Maximum-Gain Minimum-Integral Tuning method and enhanced PID control for hydraulic servo systems. A summary of each of the papers is given below.

Some Advantages of the Auto-tuning Approach in PID Control
Prof. Derek Atherton, University of Sussex

This presents an overview of the Aström and Hagglund Relay Auto-tuning method for PID controllers and compares it to the Ziegler Nichols sustained oscillation method. The approximations used in the relay design method are described as well as what can be done to take these into account. The use of hysteresis in the relay and the use of additional known networks are shown to provide additional information about the process under control.

To Automatically Select PID Structure for Various Electrical Drive Applications
Dr. Q.He, Eurotherm Drives Ltd
S.D.Garvey, Aston University

The particular structure of a PID controller influences the closed loop system response, just as the gains effect the response, and the most appropriate structure can be selected by an experienced design engineer. However, intuitive methods require a wealth of user experience and long commissioning times. Consequently most users sacrifice the optimum design by using a fixed PID structure, tuning the gains to get the desired response. This paper presents some general guidelines for selecting the most appropriate structure, and particularly for electrical servo drive applications. The concept of automatically selecting the structure is introduced.

The Maximum-Gain, Minimum-Integral Principle Applied to Materials Testing
Dr. C.E.Hinton, Instron Ltd.

This paper discusses the relatively under-used maximum-gain, minimum-integral PID tuning method from a practical, yet non-specific application viewpoint. This method maximises the gain to improve set point tracking, whilst maintaining good closed loop stability. Alternative PID structures are described, looking at interacting and non-interacting schemes. The final section presents the stability of lightly resonant systems which can be made unstable with the inclusion of derivative control action. The use of lag compensation is presented to alleviate these problems.

Self-tuning PID Control Structures
Prof. Peter Gawthrop, University of Glasgow

A theoretical summary of the generalisation of PID control is presented, with Emulator based control being described as a unification of generalised minimum variance control, generalised predictive control and internal model based control.

Tools for the Implementation of Enhanced PID Controllers and their use in Electro-hydraulic Servo Application.
Dr. Ian Whiting, Moog Controls Ltd.

Looks at the practical limitations of using standard PID control in electro-hydraulic servo applications and presents some enhancements to address them. These enhancements include an inner pressure feedback loop to reduce the resonance induced by the coupling between the load inertia and oil compliance. Another enhancement is the use of the nonlinear load characteristics within the control law. The resulting actuator response shows dramatic improvement. The tools to build the Enhanced PID Controller are part of a commercially available Programmable Servo Controller (PCS).

These Colloquium proceedings (no. 96/287) can be loaned or purchased from the IEE Library (*tel.*: 0171 344 5461, *email*: libdesk@iee.org.uk).

Report on Launch of EASY_KIT Software

The EASY_KIT Toolbox for Matlab was officially launched on the 20th February 1997 at The Advanced Control Technology Club in Glasgow. The event was well attended with 18 ACT Club members attending.

EASY_KIT is an integrated graphical front end for Matlab that allows engineers in industry to design robust controllers (PID, LQG, H2 and H_∞) without needing in-depth expertise of the various Matlab control toolboxes and associated theory.

The menu-based operation of the package makes it possible for users to implement these control designs through the intuitive graphical user interface. All the control design tasks can then be easily accessed.

After the registration and welcome, the morning session commenced with an interesting description of the new versions of Matlab (v5.0) and Simulink (v2.0) given by Simon Petrovich of Cambridge Control. Professor Mike Grimble then described the need for robust control methods and Gerald Hearns from the ICC described the underlying theory. EASY_KIT is intended to shield the design engineer from the complexities of a robust control implementation. Hence, knowledge of the rather mathematical robust control theory is not essential.

After lunch the course moved to a computer laboratory to begin a more practical session in the afternoon. Andy Clegg gave an introduction to the EASY_KIT package and this tied in with the following practical session to give the attendees a chance to try the facilities of EASY_KIT.

The feedback we got from the attendees was positive and we hope that this tool will find itself used in anger in the workplace. We welcome any comments that you have on the package as we are looking to develop this package further to provide our members with a truly useful tool.

Quantitative Feedback Theory and Frequency Domain Multivariable Design Workshop at Strathclyde

A Workshop on Quantitative Feedback Theory will be held at the University of Strathclyde on **20th-22nd August 1997**. This event will include a tutorial workshop and computer demonstrations of available software. The QFT design philosophy has been exploited in the aerospace industry in the last decade and is now finding its way into other application sectors.

Further details of this meeting may be obtained from Dr Petropoulakis at the ICC (*tel.: 0141 552 4400, email: l.petropoulakis@eee.strath.ac.uk*

If you have any comments about The ACT Club News, then please pass them to Andy Clegg.

IEE/IMechE Continuing Professional Development (CPD)

The ACT Club is an approved provider of continuing professional development with both the IEE and IMechE.

The aim of the CPD scheme is to encourage professional engineers to develop their own expertise and plan their learning needs. This will enable the engineer to remain professionally competent throughout his or her working life.

Any ACT Club activity qualifies as continuing professional development, providing there is some element of learning or training. Each activity is awarded a certain number of pdus (professional development units, the measure of CPD) depending upon the number of hours of learning and the level of interaction. For example the two day training course of Fundamentals of Control Engineering (see previous story) is worth 9 pdus and attendance at the Fault Monitoring, Diagnosis and Control Workshop would gain 2½ pdus. The pdus are entered on the engineers own Record Card which are assessed at the end of each year.

When an ACT Club activity qualifies for CPD the following logo will be shown on any related correspondence to indicate this :

IEE APPROVED PROVIDER

2½ TECHNICAL PDUS

It is hoped that current ACT Club members will take advantage of this and view it as another way in which we can help you and your fellow engineers.

ACT Club Deliverables

The following is a comprehensive list of all ACT Club deliverables, including case study reports, technical reports, educational notes and ACT Club software packages.

These Deliverables are available free of charge to ACT Club members. Please contact Andy Clegg if you would like to receive any of them.

Case Studies

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: Royal Ordnance Picrite Training Simulator (*On Going*)

SCOTTISH NUCLEAR: Control Room Alarm Analysis Toolkit (*On Going*)

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/1990)*

μ-Analysis and Synthesis (An overview of an Optimisation - Based Methodology 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 l_1 Analysis and Synthesis *(TR14/1996)*

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)*

ACT Club Deliverables (cont.)

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

Simple Introduction to Kalman Filtering *(EN07/1996)*

ACT Club Software

EASY_KIT Toolbox for MATLAB

EASY_KIT is an integrated graphical front end for MATLAB that allows engineers in industry to design robust controllers (PID, LQG, H_2 and H_∞) without the need for in-depth expertise of the various MATLAB control toolboxes and associated theory. The package integrates all the general stages of control design, including plant model specification, weighting function tuning, frequency and time responses and linear or non-linear simulations. A worked example looks at the dynamic ship positioning problem and an on-line tour guide of the package is included.

Self-Tuning Control Software

This linear identification and control design tool for MS-DOS uses Recursive Least Squares algorithms (Peterka's square root filtering or Bierman's UD factorisation) to identify a discrete plant model. Controllers can be specified as open loop, fixed gain PID, self-tuning PID, self-tuning LQG, self-tuning H_∞ or self-tuning generalised predictive control (GPC). The ability to interface to a real plant via a serial communications link is included, and is specifically set-up for a Turnbull TCS controller. This can be re-programmed by the user for use with other systems.

Nonlinear Self-Tuning Control Software

This is an extension of the above Linear Self-tuning Control Software package, where the identification and plant can now include nonlinear elements. A Recursive Extended Nonlinear Least Squares algorithms (using Bierman's UD factorisation) is used to identify the discrete plant model and the same controllers as provided in the Linear Self-Tuning package are available. The ability to interface to a real plant via the serial link still exists. The improved user interface now works under MS-Windows.

Multivariable Robust Control Toolbox for MATLAB

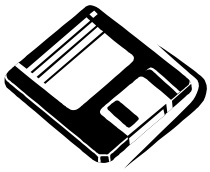
This package is used to design and test optimal multivariable robust controllers and acts as a Graphical User Interface extending the MATLAB Robust Control Toolbox. Both LQG and H_∞ controllers can be designed using either the state-space approach (using the Robust Control Toolbox) or the polynomial approach (internal to the MRC Toolbox). The analysis can be in either frequency or time domain.
Note: This toolbox operates in the OpenWindows or X-Windows environments running on a Sun workstation.

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

This toolbox complements the MATLAB Robust Control Toolbox by implementing robust controller designs, either H_2, H_∞ or mixed H_2/H_∞, using the polynomial approach. An interactive menu allows the user to enter plant models, gains and weightings associated with the controller. Both frequency and time domain analysis of open loop and closed loop systems may be performed. Includes four design examples and an on-line tour guide of the package.

H_∞ Robust Control Toolbox for MATLAB

This toolbox is intended for solving some frequently encountered scalar LQG and H_∞ control problems, both in continuous and discrete time. Generalised or mixed sensitivity H_∞ controllers or standard or generalised LQG controllers can be specified, coupled with appropriate filter elements for the weightings. Both frequency and time domain analysis of closed loop systems are available.



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