

DIGITAL COMPUTER CONTROL OF PROCESSES

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COMPUTER PROCESS CONTROL, as space travel, is no longer a dream but a reality. The time when every new plant of significant size will be equipped with a control computer is rapidly approaching. Recognizing this fact the Department of Chemical Engineering at LSU initiated six years ago a course on the use of digital computers in process control. This graduate course is one of four offered by the department in the area of automatic process control:

Course Title	Level
Introduction to Automatic Control Theory	Senior/Graduate
Process dynamics and adaptive control	Graduate
Optimal control of processes	Graduate
Digital Computer Process Control	Graduate

The first of these courses is a pre-requisite to the other three which are independent of each other. Each of the graduate courses covers different aspects of modern control theory with actual or potential application to chemical processes. As

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a matter of historical interest, two of these courses were initiated over two decades ago by the late Arthur G. Keller, as survey courses in process instrumentation and control.

The objective of the course is to familiarize the student with the control capabilities of the digital computer and with the techniques he will need to design the control routines to be executed by the computer. The course outline given in Table I is a list of the topics covered.

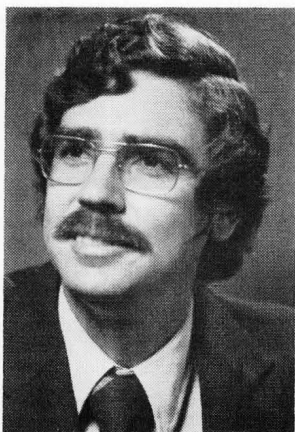
Table I
COURSE OUTLINE

- I. Introduction
 1. Review of automatic process control theory
 2. Description of the computer hardware necessary for real-time operation
 3. Programming the computer for real-time operation
 4. Economic justification
- II. Design of Sampled-Data Control Systems
 1. The algebra of z-transforms
 2. Stability of sampled-data systems
 3. Effect of noise and digital filtering
- III. Feedback Control Algorithms
 1. Synthesis of control algorithms
 2. Discrete equivalent of standard two- and three-mode controllers
 3. Process models and tuning techniques
 4. Effect of sampling interval
- IV. Advanced Control Techniques
 1. Feedforward control
 2. Cascade control systems
 3. Interaction index and decoupling of multi-variable systems
 4. On-line identification and adaptive control
 5. Compensation of transportation lag
- V. Optimization of Process Operation
 1. Formulation of the optimization problem and the performance index
 2. Linear programming and constrained optimum
 3. On-line search methods

CONTROL LOOP ANALYSIS

A REVIEW OF AUTOMATIC control theory is given in the form of an analysis of the different components of the typical control loop. Special attention is devoted to the conventional two- and three-mode analog controllers for later comparison with the digital version of the feedback controller. As part of the introduction the student, who is usually familiar with programming the computer for "batch" solution of scientific problems, is exposed to the special hardware and programming considerations required for "real-time" operation, i. e. continuous attention of a process that takes place in actual time. The significant factors involved in economically justifying a computer in a process control application are also presented.

The course as taught at LSU uses z-transform



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algebra as a tool in the analysis of the sampled-data control loop, and in the synthesis of digital control algorithms. Pulse transfer functions and their use in the determination of the stability of the loop are given particular attention, as are the most common forms of data holds on the computer output signals. The effect of noise on the sampling process and its attenuation by digital filtering are also presented.

The synthesis of digital control algorithms is illustrated by the presentation of the deadbeat, Dahlin and Kalman algorithms. These algorithms will, under certain conditions, cause excessive switching of the control valve, a phenomenon known as "ringing". As a result of a term project assigned to one of the students in the course, a demonstration of ringing utilizing the Chemical Engineering Hybrid Simulation Laboratory has been developed. The demonstration consists of a continuous stirred tank chemical reactor, simulated on the analog computer and controlled by the digital computer through the hybrid interface. (See Table II). Given this set-up the student is able to obtain a model of the process, synthesize a digital control algorithm which is programmed on the digital computer, and observe the effect of ringing. He is also able to identify and remove the ringing poles in the control algorithms and observe the performance of the

Table II

HYBRID COMPUTER HARDWARE

Analog Computer

Electronic Associates Model 680
 75 operational amplifiers
 30 integrator/summer networks
 20 multipliers/square/square-root cards
 2 adjustable function generators
 Assorted parallel logic: AND gates, FLIP FLOPS, etc.

Hybrid Interface

Electronic Associates Model 693
 24-channels of analog-to-digital conversion
 12 channels of digital to analog converters
 16 digital output lines (logic levels)
 8 digital input lines (logic levels)
 6 interrupt lines

Digital Computer

Xerox Model Sigma-5
 20,000 words, 32 bits per word
 Hardware floating-point unit
 750,000 bytes of bulk storage (disk)
 Card reader
 Line printer
 Operator's console
 6 levels of priority interrupt

Software

Sigma Macro-symbol assembler
 FORTRAN compiler
 SL-1 Simulation Language
 Hybrid subroutine package (FORTRAN callable)

A demonstration of ringing using the ChE Hybrid Simulation Lab has been developed. It consists of a continuous stirred tank chemical reactor simulated on analog computer, controlled by digital computer through hybrid interface.

"ringing-free" algorithm. The set-up can also be used to test the different methods of obtaining simple models of a process, and to observe the effect of varying the computer sampling interval.

OBSERVING COMPUTER RESPONSE

MANY OF THE INDUSTRIAL applications of digital control computers involve the use of discrete equivalents of the conventional analog two- and three-mode controllers. A number of methods to tune the parameters of the analog controllers have been adapted to their digital counterparts. These include Zeigler-Nichols, Cohen and Coon, and a number of empirical formulas de-

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veloped under the project THEMIS research grant at LSU. Formulas for all of these methods have been programmed as a subroutine that computes the parameters of the control algorithm given the modes, the sampling interval and the parameters of a first-order plus dead-time (transportation lag or time delay) model of the process. The students use this subroutine, also the subject of a former term project in this course, to observe the responses produced by the different formulas on systems simulated on the hybrid computer.

The justification of digital control computers is usually based on the ease and economy of implementing control techniques more sophisticated than simple feedback. The advanced techniques of feedforward control, cascade control, elimination of loop interaction through decoupling, on-line identification for adaptive control of nonlinear processes, and dead-time compensation are covered from the point of view of digital versus analog implementation. Term projects in these areas are assigned to individual students. Although use of

the hybrid computer is encouraged with views to the development of demonstration problems, the students do not always comply.

The optimization of steady-state process operation was the first type of computer control applications and is still one of the most popular. 20—CHEM. ENGINEERING — 12281 — Jerry Although the subject of optimization is covered in detail in another graduate course, an overview of the problem is presented from the point of view of on-line application to processes.

The text used in this course is "Digital Computer Process Control," published by Intext (1972) and authored by Dr. Cecil L. Smith, Chairman of the Department of Computer Science at LSU and originator of the course. In addition, a collection of articles covering specific topics is used as reference material.

In summary, this course offers fairly complete coverage of the subject of digital computer control of chemical processes, plus a working control of chemical processes, plus a working experience through the use of hybrid simulation of digital control loops. Since the subject matter is in a state of rapid development, the course itself is in a state of evolution. The students contribute to this evolution through their term projects and through constructive criticism of the subject matter and methods of presentation. □



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