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Computer control of real-time processes



Edited by
**S. Bennett
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Preface

This book is based on the lectures given at a Vacation School for postgraduate students in the areas of Control and Instrumentation held at the University of Sheffield in March 1990. For many years the Information Technology Directorate of the Science and Engineering Research Council has sponsored Vacation Schools, and this is the fourth school on the topic of computer control to be arranged by the Department of Control Engineering, University of Sheffield. Previous schools held in 1980, 1984 and 1987 led to the publication of books entitled *Computer Control of Industrial Processes*, *Real-Time Computer Control*, and *Computer Control*. The continually changing nature of the subject has led to the courses being re-structured on each occasion to reflect the current state-of-the-art, trends and possible future directions in the field. The Organizing Committee, Professor D.P. Atherton, Mr. C. Clark, Mr. P.C. Hammond, Professor D.A. Linkens, Dr. J.D.F. Wilkie played a major role in the planning of the course structure and we are grateful for their assistance. We also thank Mr. J.C. Leonard of the Science and Engineering Research Council for his advice and assistance.

The course had four major themes: design and tuning of controllers; the hardware technology; software design; and examples of applications. The first of the themes - design and tuning of controllers - is covered in chapters 1 -4. In chapter 1 Leigh covers discrete controller design for single-loop systems and in chapter 2 Virk deals with the design of controllers for multivariable systems. Methods of automatic tuning for commercial PID controllers are surveyed by Gawthrop chapter 3 and in chapter 4 practical aspects of implementing and tuning PID controllers are discussed by Smith.

The second theme - hardware technology - is introduced by Henry with a discussion of PLCs and their applications (chapter 5); Barney in chapter 6 covers networking technology for distributed computer control systems; and Virk deals with the technology of parallel processors for computer control applications (chapter 7).

Software design is introduced by Bennett in chapter 8 with a discussion of the particular problems of designing software for real-time control. In chapter 9, Mort describes one particular methodology, MASCOT, for the development of real-time software. Techniques for introducing fault tolerance into real-time software are described by Bennett in chapter 10. And in chapter 11 an example of the application of an object oriented approach to software design is described by Stanley.

The applications of computer control covered include control of robots (Morris, chapter 14), patient care including computer control of intensive care, anaesthesia and drug therapy (Linkens, chapter 13); batch control of sugar refining processes (Wilkie, chapter 16); modelling simulation and control of liquid gas vaporisers (Lees, chapter 12) and active control of fighter aircraft (McLean). Participants on the course also had the

benefit of visits to ICI Huddersfield and to BSC Stainless, Sheffield where they were able to see applications of computer control: we thank the two companies for arranging the visits.

We are grateful for the support received from the staff and students of the Department of Control Engineering, University of Sheffield and thank them and Professor D.A. Linkens for making available the facilities of the Department for the course. Particular thanks are due to Mrs. Margaret Vickers and Mr. R.D. Cotterill for administrative support. We also thank all the lecturers who contributed to the course and to this book. The preparation of the book was well supported by Mr. J.D. StAubyn of Peter Peregrinus and we thank him for his understanding and patience. Finally we acknowledge the financial support of the Science and Engineering Research Council that made running the course possible.

Dr. S. Bennett
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Contents

Preface

1	DISCRETE CONTROLLER DESIGN by J.R. Leigh	1
1	Introduction	1
2	Approaches to algorithm design	1
2.1	Direct controller synthesis	1
2.2	Gain plus compensation approach	2
3	Discussion of the design approaches	3
3.1	Direct controller synthesis	3
3.2	Gain plus compensator approach	6
4	Choice of sampling interval T	7
5	Special algorithms	8
5.1	Dead beat control	8
5.2	Takahashi's algorithm	8
5.3	Adaptive control	9
5.4	Predictive iterative control	10
6	Limits to attainable performance	10
7	Overview	11
	References	12
2	MULTIVARIABLE CONTROL SYSTEM DESIGN by G.S. Virk	14
1	Introduction	14
1.1	Theorem: multivariable Nyquist stability criterion	16
1.2	Definition	17
1.3	Definition	17
1.4	Theorem	17
2	Inverse Nyquist array	18
2.1	Theorem	19
2.2	Theorem	19
2.3	Achieving dominance	20
3	Multivariable root-loci	21
3.1	Uniform rank systems	22
4	State-space methods	24
4.1	Definition: controllability	26
4.2	Definition: observability	26
4.3	Theorem	26
4.4	Linear state variable feedback	27
4.5	Output feedback	27
4.6	Observers	28
5	Optimal control theory	31
5.1	Definition	32

5.2	Theorem	32
5.3	Dynamic programming for discrete LQP problems	33
6	Conclusion	35
	References	36
3	AUTOMATIC TUNING OF COMMERCIAL PID CONTROLLERS by P.J. Gawthrop	37
1	Introduction	37
2	The continuous-time self-tuning PID control algorithm	38
2.1	The modified system model	40
2.2	The zero-gain predictor	41
2.3	PI and PID controllers	42
2.4	The multivariable version of the algorithm	43
3	First application: a set of laboratory tanks	45
3.1	Experimental equipment	45
3.2	Mathematical model	46
3.3	Single loop experiments	47
3.4	Two-loop experiments	48
4	Second application: temperature control of a plastics extruder	49
4.1	Problems in controlling extrusion processes	49
4.2	Zero screw speed	50
4.3	Variable speed screw	50
5	Conclusions	51
	References	52
4	PRACTICAL ASPECTS OF IMPLEMENTING PID CONTROLLERS by L.S. Smith	58
1	Introduction	58
2	Input conversion	59
2.1	Time resolution	59
2.2	Amplitude resolution	61
3	Control algorithms	63
3.1	Proportional action	64
3.2	Integral action	65
3.3	Derivative action	66
3.4	Bumpless transfers	69
4	Output conversion	70
4.1	Time-proportional outputs	71
4.2	Motorised-valve positioners	73
5	Tuning techniques	75
6	Communications	77
7	Conclusions	79
	References	80
5	GENERATING SEQUENCES FOR CONTROL by R.M. Henry	81
1	Introduction	81
2	How sequences used to be generated	82
2.1	Using switching logic	83
2.2	Using relays	83
2.3	Sequential logic	84
2.4	Timing	84
2.5	Timing in ladder logic	85
2.6	Counting	85

3	Implementing logic features on a PLC	85
3.1	Internal organisation	85
3.2	The PLC's software	86
3.3	User programming	86
4	Aids to program development	87
5	Putting a PLC to work	87
5.1	State transition matrix	88
5.2	Sequencing and sequences	89
5.3	Nets and the co-ordination of parallel subsequences	89
5.4	Software Engineering	90
5.5	Testing	92
6	The advantages of using PLCs	93
7	Other PLC functions	93
7.1	Continuous control	94
8	Don't these PLCs have any disadvantages?	95
9	Where next for PLCs	95
10	Conclusions	96
	References	96
6	REAL-TIME COMPUTER NETWORKING by G.C. Barney	97
1	Distributed control systems	97
2	Interconnecting devices	98
3	Serial computer and equipment connections	99
3.1	The terminal port	99
3.2	Character coding	100
3.3	Asynchronous equipment connection	101
3.4	Commentary	101
4	Communication standards	102
4.1	The ESO seven-layer model	102
5	Local area networks	103
5.1	LAN topologies	103
5.2	Access methods	105
5.3	Comparison	106
6	LANs in a control environment	106
	References	108
7	PARALLEL PROCESSING FOR COMPUTER CONTROL by G.S. Virk	109
1	Introduction	109
2	Occam overview	114
3	Occam and transputer implementation	115
4	Example: control of flexible structure systems	117
4.1	Master task scheduler	121
4.2	System simulation (p1)	122
4.3	Modelling	123
4.4	Controller design	125
5	Conclusion	126
	References	127
8	DESIGN OF SOFTWARE FOR REAL-TIME SYSTEM by S. Bennett	129
1	Introduction	129
1.1	Classes of real-time systems	131
1.2	Task - a definition	131
1.3	Program classification	132

2	Design strategies	134
2.1	Single task	134
2.2	Two-tasks (foreground-background)	135
2.3	Multiple task	136
2.4	Virtual machine	136
2.5	Design guidelines	137
3	Design techniques and tools	140
3.1	Introduction	140
4	MASCOT	140
4.1	Outline	140
4.2	Simple example	141
4.3	Run-time features	143
4.4	Summary	144
5	SDRTS: structured development for real-time systems	145
5.1	Introduction	145
5.2	Modelling notation and techniques	145
5.3	Essential modelling	147
5.4	Checking the essential model	151
5.5	Implementation	151
6	Timing considerations	152
6.1	Example 1	152
6.2	Example of cyclic tasks	153
6.3	Example of timing of cyclic tasks	155
7	Conclusions	156
	References	156
9	REAL-TIME SOFTWARE USING MASCOT by N. Mort	159
1	Introduction to MASCOT	159
2	The MASCOT kernel	161
3	Modularity in MASCOT	161
4	MASCOT activities and IDAs	162
5	MASCOT network (ACP) diagrams	163
6	Activity scheduling and subsystems	165
7	Process synchronization	167
8	Operations in MASCOT	168
9	A MASCOT example - Naval AIO system	169
10	Recent developments - MASCOT 3	172
	References	172
10	SOFTWARE FAULT TOLERANCE by S. Bennett	173
1	Introduction	173
2	Reliability definitions	173
3	Use of redundancy	174
4	Fault tolerance	176
4.1	Fault detection measures	178
4.2	Fault detection mechanisms	181
4.3	Damage containment and assessment	181
4.4	Fault recovery measures	181
4.5	Special features of real-time systems	183
5	Conclusions	185
	References	185

11	AN OOD METHODOLOGY FOR SHOP FLOOR CONTROL SYSTEMS by N.K. Stanley	186
1	Introduction	186
2	Object-oriented design	186
2.1	Overview	186
2.2	Object-oriented design approach	187
3	High-level design process	189
3.1	Overview	189
3.2	Step 1: define the objects for each functional area	190
3.3	Identification of internal program interfaces (IPIs)	198
3.4	Step 2: technical review	199
3.5	Step 3: combine the functional areas to form the system	200
3.6	Step 5: formal documentation of objects	202
3.7	Step 6: HLD formal inspection	203
4	Conclusions	203
	References	204
12	MODELLING, SIMULATION AND CONTROL OF DIRECT FIRED LIQUID GAS VAPORISERS by A. Lees	205
1	Introduction	205
2	Vaporiser control	205
3	Modelling and identification	206
4	Model validation and control system design	207
5	Control system performance	208
5.1	Comments	209
6	Implementation of the control strategy	209
6.1	On-site validation of control strategy	209
7	Conclusions	210
	References	210
13	COMPUTER CONTROL FOR PATIENT CARE by D.A. Linkens	216
1	Introduction	216
2	Post-operative blood pressure control	217
3	Anaesthesia control	221
3.1	Drug-induced unconsciousness	221
3.2	Drug-induced muscle relaxation	223
3.3	Post-operative pain relief	225
4	Control of blood glucose levels	226
5	Control of respiratory variables	229
6	Anti-coagulant therapy	230
7	Computer-aided drug therapy	230
8	Expert control	231
9	Conclusions	233
	References	235
14	ROBOT CONTROL by A.S.Morris	239
1	Introduction	239
2	Requirements and constraints for robot manipulator control	239
3	Manipulator geometry	240
4	Drive systems	240
5	Programming	252
6	Sensors	243
7	Kinematic modelling	243

8	Standard homogeneous transformations	246
9	Denavit-Hartenburg manipulator representation	247
10	Kinematic equations of a real robot	248
11	Inverse kinematic relationships	250
12	Dynamic models	250
13	Robot dynamic control	252
14	Conclusions	254
	References	254
15	ACTIVE CONTROL OF A MODERN FIGHTER AIRCRAFT by D. McLean	256
1	Introduction	256
1.1	Fighter aircraft characteristics	256
1.2	Active control technology	256
1.3	ACT functions	247
2	Mathematical model of a fighter aircraft	258
2.1	Rigid body motion	
2.2	Dynamics of a flexible aircraft	260
2.3	Bending moments	262
3	Atmospheric turbulence	263
3.1	The nature of turbulence	263
3.2	Continuous gust representation	263
3.3	State variable representation of atmospheric turbulence	264
4	ACT systems	265
4.1	Stability augmentation system	265
4.2	Gust load alleviation (GLA) and bending mode control (BMC)	266
4.3	Ride control systems	268
5	Conclusion	271
	References	271
16	BATCH PROCESS CONTROL by J.D.F. Wilkie	274
1	Introduction	274
2	Batch processes in the beet sugar industry	275
3	The vacuum crystallisation of sugar	275
4	Control systems for vacuum pan crystallisation	279
5	Equipment for batch process control	281
6	Experience and benefits	282
	References	283
17	DDC IN THE PROCESS INDUSTRIES by D.J. Sandoz	286
1	Introduction	286
2	The elements of a computer control systems	287
3	Hardware for the computer systems	297
4	Integrity of computer control systems	299
5	The economics of computer control systems	300
6	Future trends	301
7	Conclusions	302
	Index	304

Chapter 1

Discrete controller design

J. R. Leigh

1) Introduction

The title, being interpreted, means the theory and practice of discrete time control (ie. the sort that is implementable in computers) to achieve closed loop control of continuous time processes. Thus, we are concerned with the discrete time control of continuous time processes within a hybrid feedback loop, figure 1. A natural initial question suggests itself: what are the advantages of discrete, as opposed to continuous, controllers? The answer is very disappointing. As far as control theory is concerned, there are no advantages. (Proof: every realisable discrete time signal is a continuous time signal but the converse is false). The reason for studying discrete time control is essentially practical: to allow reliable miniature low-cost digital electronic devices to be used as controllers.

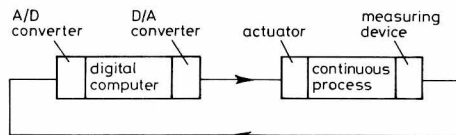


Fig. 1 A continuous process under closed-loop digital control

2) Approaches to algorithm design

Roughly, there are two approaches:

2.1 Direct Controller Synthesis

Procedure in outline:

- i) Convert the specification that the final system must meet into a desired transfer function $H(z)$.

2 Discrete controller design

- ii) Produce a transfer function $G(s)$ representing the process that is to be controlled.
- iii) Form the transfer function $G'(s) = G_o(s)G(s)$, where G_o is a model of the interface between controller and process.
- iv) Discretise the transfer function $G'(s)$ to produce the discrete time equivalent $G'(z)$.
- v) Use the relation $D(z) = H(z)/\{G'(z)[1 - H(z)]\}$ (1) to synthesise the necessary controller for insertion into the loop (see figure 2).

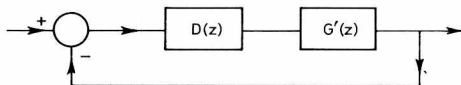


Fig 2. Synthesis in the z-domain

- vi) Convert $D(z)$ into a difference equation and use it as a real time algorithm.

Comment

It can be seen that equation 1 contains models both of the process and the desired behaviour. In effect, the controller cancels out the existing process characteristics and replaces them by those of the required system.

2.2 Gain plus compensation approach

Idea in outline

- i) If a controller consisting of only a simple gain of numerical value C is used as in figure (3) then the performance of the resulting system (of transfer function $CG(z)/[1 + CG(z)]$) may be manipulated by choice of the value for C .

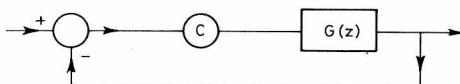


Fig 3. A controller consisting of a simple gain C

- ii) As C is increased, the speed of response of the system increases but in general the response becomes oscillatory and as C is increased further, the system becomes unstable.
- iii) By incorporating a suitable compensator M into the loop (figure 4) 'improved stability characteristics' can be given to the loop and then the value of C can be further increased with a consequent increase in speed of response. This process of juggling the design of compensator M and the value of gain C can be iterated until a best possible response is achieved.

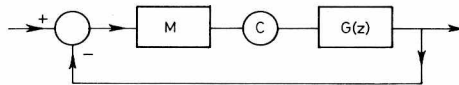


Fig 4. Incorporation of a compensator M into the loop

3) Discussion of the design approaches

3.1 Direct Controller Synthesis

- i) Conversion of the specification into a desired transfer function $H(z)$

This step will very often involve a considerable amount of approximation - particularly in those frequently encountered cases where the original specification is expressed in terms far removed from those pertaining to transfer functions.

However, if the specification can be expressed in terms of a desired natural frequency and a desired damping factor then figure 5 may be used directly to choose the poles of $H(z)$.

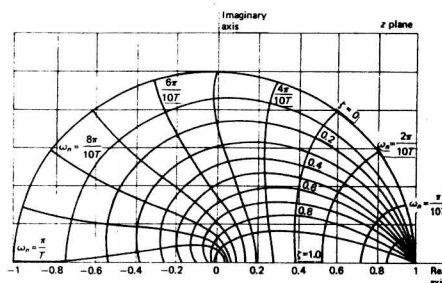


Fig 5. Diagram to assist in choosing the poles of $H(z)$