Computer control of real-time processes

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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.

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Contents

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.

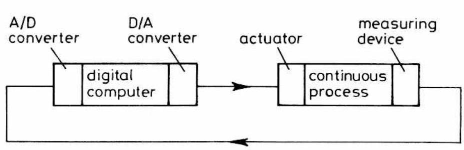

Fig. 1 A continuous process under closed-loop digital control

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).

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).

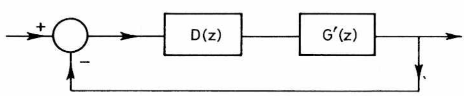

Fig 2. Synthesis in the z-domain

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.

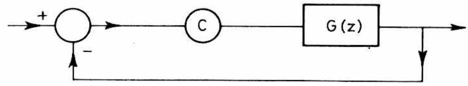

Fig 3. A controller consisting of a simple gain C

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.

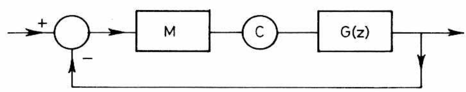

Fig 4. Incorporation of a compensator M into the loop

3) <u>Discussion of the design approaches</u>

3.1 <u>Direct Controller Synthesis</u>

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).

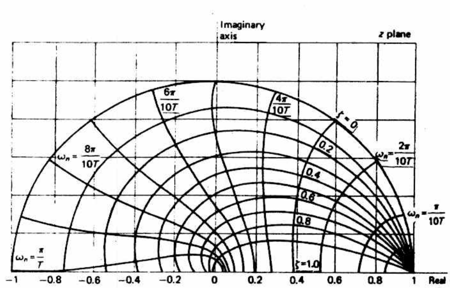

Fig 5. Diagram to assist in choosing the poles of H(z)