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COMPUTER-AIDED CONTROL DESIGN SYSTEMS

A THESIS

PRESENTED IN PARTIAL FULFILMENT

OF THE REQUIREMENTS FOR THE DEGREE

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SYNOPSIS

This thesis is concerned with the application of interactive computer-aided design techniques. These techniques are graphical and based upon conventional control theory. They are the time-response, frequency-response and root-locus techniques.

The design philosophy based on the above design techniques is that an appropriate compensator is inserted and the overall system performance is studied. The graph representing the system performance after each adjustment of the compensator is adjusted until the performance specifications are met.

The Computer techniques are developed which, having specified the fixed configurations of the original system, permit varied choice of the compensator. For each selection, the control system may be investigated in either open- or closed-loop form. The software for computer-aided control system design is programmed in Algol and operates on the Massey University B6700 computer system.

The program is operated via a Tektronix 4010 visual display terminal in an online interactive mode. The control designer, at the Tektronix console, is able to specify certain designs and evaluate their effectiveness in terms of various graphical analyses produced by the computer and displayed on the screen of the Tektronix.

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CHAPTER ONE

INTRODUCTION

This thesis is concerned with the application of computer-aided design to classical control theory. In classical control theory, much of the effort of control system design is concerned with the generation of charts for such aspects as time response, root locus and frequency response characteristics. These charts are time consuming to prepare by hand, even though short cut techniques are often available to obtain sketches which closely approximate the actual characteristics.

A digital computer is able to assist in these conventional design procedures by generating the appropriate charts for inspection by the designer, thereby taking much of the manual effort out of the design processes.

This thesis describes the development of an interactive design package. Software for computer-aided control system design has been programmed to operate, via a visual display terminal, in an online interactive mode. The control designer, using the terminal console, is able to specify certain designs and evaluate their effectiveness in terms of the various graphical analyses produced by the computer and displayed on the screen of the terminal.

The computer-aided approaches to control system design are applicable to linear models. Although this assumption of linearity is not exactly valid for most practical systems, it is a realistic approach for three reasons:

1. Many systems are essentially linear under normal operating conditions.
2. Slightly nonlinear systems usually may be approximated with sufficient accuracy by assuming linearity.

3. At present adequate mathematical methods for solving non-linear equations have not been developed.

In this thesis, the system characteristics are determined by time-response, frequency-response and root-locus methods. The time-response method is a direct way of considering the system performance in the time-domain. The output response is derived for given inputs. The direct solutions of the differential equation of the system following a step input are plotted on an "output versus time" graph. The system performance is specified in terms of the information obtainable from this graph.

For the frequency-response methods, the frequency of sinusoidal oscillation of the input signal is varied over a certain range and the resulting frequency-response is studied. The results are plotted on graphs such as the Bode diagrams, Nyquist diagrams and Nichols charts. The root-locus method is a graphical method used to evaluate the roots of the characteristics equation of the system transfer function and determine the influence of the system parameters on these roots. This method provides a very effective way to carry out many design problems with requirements specified in the time-domain.

The design philosophy based on the above graphical approaches is that the graph representing the system performance, obtained by any of the above methods, is shaped and reshaped until the performance specifications are met. To achieve this, appropriate compensation networks are usually required within the control system structure.

Computer techniques have been developed which, having specified the fixed configurations of the control system, permit varied choice of the compensator. For each selection, the control system may be investigated - either in open- or closed-loop form - using

any of the above methods. The software for computer-aided control system design is programmed in Algol and operates on the Massey University B6700 computer system. The interactive terminal is via a Tektronix 4010 visual display unit. The designer, at the Tektronix console, is able to adjust the designs in order to improve the system performance by shaping various graphs displayed on the screen of the Tektronix. Given a particular control system structure, which may be either open-loop or closed-loop, the designer may request the following options:

- A display of the system time response following a step input.
- A Bode diagram display of the system frequency response.
- A Nyquist diagram display of the system frequency response
- A Nichols chart display of the system frequency response.
- A Root-locus plot display of the roots of the system characteristic equation as the system gain varies.

The designer seeks to satisfy all performance specifications by means of educated trial-and-error repetition. Although the design is based on a trial-and-error procedure, the experience of the designer plays an important role in a successful design. An experienced designer will be able to achieve an acceptable system design using fewer trials.

Chapter Two in this thesis describes the analysis and design techniques that have been utilized, namely time-domain, frequency-domain and root-locus techniques. Chapter Three outlines the structure of the software for computer-aided control system design, detailing the methods employed to implement some of the concepts discussed in chapter two, and also specifies how the system is used. Chapter Four presents several illustrative design examples, along with the computer generated graphs.

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