CHAPTER I

INTRODUCTION

Optimal and adaptive control has become the major area of automatic control research in recent times. A control system which is designed for the best possible performance according to a suitable performance index under the given limitations and constraints is known as the optimal control system. An important system performance which is often required to be optimised is the transient response of the system. Design of physical systems involves the selection of proper design parameters which will ensure optimum transient behaviour. Dead beat response is often desired for step inputs which gives a fast response with zero overshoot. A fast response can be obtained by a lightly damped system but this is associated with large overshoot and prolonged oscillations. The posicast control first proposed by O.J.M. Smith[9] is a well recognised technique for getting dead beat response for lightly damped systems. In this technique, the step input is properly modified before applying to the system. For a second order system the modified input consists of an initial step and a delayed step applied at such an instant that the error of the system becomes zero and the error rate attains its first zero at the same time.

The next step in the sophistication of a control system is to design a system which is self-optimizing or 'adaptive' and can automatically take care of changes in system parameters and/or environmental influences. Living organisms are equipped in a variety of ways to cope with their environment. They make physiological adjustments that enable them to cope with fluctuations in their immediate environments. These adjustments are known as 'adaptations'. The term 'adaptive control' is thus coined from biology. Since physical systems also work in widely varying environmental conditions, it is desired that they should possess the properties of adaptation or self organisation. Interesting results have been obtained recently in the modelling of various functions of living organisms in engineering systems.

The control engineer has been faced with the problem of controlling systems having uncertainties in their dynamics. The feedback principle solves this problem to some extent but when parameter variations become very large, the concept of adaptation plays a big role. During the last twenty years or so, considerable research work has been done in theory and applications of adaptive concepts in the control systems. An adaptive control system in some form or other should be able to perform three basic functions : (i) provide information about the system dynamics either continuously or at least at some discrete instants; (ii) makes a decision to achieve the optimum performance; and finally (iii) initiate a proper actuating mechanism so as to drive the control system towards the optimum. These three operations necessary for the adaptive systems are known as identification, decision and actuation respectively.

Realization of identification and decision in a control system calls for circuitry with high precision and computer facilities. Both these require the use of digital circuits. During the last decade, digitalization of electronics is becoming very common and there have been dramatic improvements in the digital circuitry which is highly reliable. High speed, miniaturisation and precision is easily achieved using digital circuitry. Digital systems are free from the calibration problems. To combine the better features of both digital and analog circuits, hybrid techniques may also be used. Digital and hybrid systems have tremendous potential and are useful in all precision measurements, process control instrumentation, computers and communication systems. The advent of integrated circuits has reduced the size and cost of the electronic circuits. It has further increased the fascination for using digital electronic circuits for the purpose of control.

Uses of digital circuits are increasing in the control systems. Mohleji and Thomas[1], have described an optimal control scheme for third order systems using switching techniques. A self adjustable threshold logic element (adaline) has been successfully used by Widrow[2-4] and others for adaptive control and many other applications like pattern recognition. Montogomerie et al.[5] describe a method for closed loop digital control.

The large complex control systems can best be controlled by employing a digital computer or computer-like devices. At the same time simple control loops continue to be made up of simple analog electrical, pneumatic or similar devices. To satisfy both the requirements, therefore, simple control tasks can be performed by simple analog type of control systems while for improved performance a separate loop utilizing digital controllers is required.

We are faced with the following problems :

(a) To design controllers for obtaining dead beat response for step inputs.

(b) To provide provision for the adjustment of controller/system parameters so as to compensate the effects of changes in plant parameters due to the environmental influences.

(c) Digital electronic circuits should be used as far as possible for the controller and adjusting mechanism so as to give proper accuracy, reliability and ease.

Some works on these topics have been described in this report. Chapter II describes the theory and design of posicast controllers for obtaining dead beat response for step inputs. Posicast controllers using solid state switching circuits are described for systems of second and higher orders. The scheme also works satisfactorily for the inputs of other types.

Chapter III gives a review of adaptive systems. Literature on adaptive systems has become enormous, and can be put under following main headings :

1. Model-reference techniques.

2. Hill-climbing techniques.
3. Design based on sensitivity approach.
4. Optimal adaptive schemes.
5. Automaton controllers.

A study of different adaptive schemes was done and some of the methods are described in this chapter. Model reference adaptive systems with different design methods are described in detail. Various types of devices which are used for adaptive control are also scanned.

Chapter IV describes many electronic devices which are suitable for adaptive control. The parameters of these devices are adjustable by digital binary coded inputs. These types of devices are not only useful for the purpose of realizing adaptive posicast scheme but can be used in many cases where an adaptive approach is required. The design approach for using such devices is to keep the cost of potential production versions to a minimum, while retaining the advantages of using digital devices over analog devices. The advantages include higher accuracy, freedom from drift, freedom from routine maintenance, ease of working and compatibility with larger digital systems. The digitally controlled devices described are, digitally controlled variable gain amplifier, digitally controlled compensation network, digitally controlled delay generator and digitally controlled variable frequency sampler. All these devices are suitable for digital adaptation.

In Chapter V, sequential switching circuits (finite state machines) are described for updating the parameters of the controller so as to keep the performance of the overall system closed to an optimum performance. A scheme for keeping the value of damping factor of a system within acceptable limits inspite of large variations in the plant parameters has been described. Finite state automata type of controllers described here utilize the information, received by identification of some characteristics of the output, for generating the next better value of the parameters. The process continues until the acceptable performance is achieved. Because of high speed of the switching circuits, the optimum parameter value is reached in a small time. The adjustments of the parameter is done at discrete instants by digital binary coded inputs which are the outputs of the finite state machine. The rate of adjustments of the parameters of the controller can also be varied.

Chapter VI gives another technique for adaptive control. In this chapter a controller is designed which utilizes the gradient technique for updating the parameter values of the controller. This scheme is more general and has been applied for minimizing the mean square error type of performance index.

A joint study of Biology and control systems is very essential in understanding the biological systems and to design better physical control systems having characteristics of the living beings. Chapter VII is an attempt in this direction and here a model for the human operator is proposed. This chapter emphasizes that the human operator is equipped with similar devices as described in Chapter IV. The neurons which are of fundamental importance in information processing network of central nervous system can have only two states, namely it can be either fired or quiet, depending upon its inputs and threshold. In the proposed model, information exists in binary coded form and decision are taken by finite state automata type of machines. The outputs of the finite state machine are used for updating the human operator's own parameters. This ensures an optimum performance from the human operator in executing a certain task even in the time varying environmental situations.