# MODEL REFERENCE ADAPTIVE CONTROL SYSTEMS

Thesis Submitted for the M.Sc. Degree to the

Electrical Engineering Department

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# CHAPTER 1

# I N T R O D U C T I O N (1,2)

## 1.1 Historical Background of Adaptive Control.

The second half of the 1950s have been notable in the field of automatic control for the phenomenal growth of interest in the concept of adaptive control or control in which automatic and continual measurement of the process to be controlled is used as a basis for the automatic and continuing self-design of the control system. The term "adaptive" appeared in control literature around 1954, when Tsien[3] described Ashby's[4] model of human brain. About the same time, Benner and Drenick[5] presented a control design with "adaptive" characteristics. Since that time, the term "adaptive" has been attached to a wide variety of control systems.

## 1.2 The Purpose of Adaptive Control Systems[6-8]

Any feed - back control system can be considered a passive adaptive control feed-back system. For example the conventional single-loop configuration can be considered adaptive if attention is focused on the feed-back gain which tends to reduce the effects of any variation of process parameters. Our concern is focused on Active Adaptive systems, which is known as process adaptive systems.

A process adaptive system is one which determines the values of the significant parameters in the physical process and uses these values to program the controller according to the specified control laws to give the desired performance.

Therefore, for any control system described by a set of differential equations whose parameters vary with time in an unpredicted manner due to environmental changes, the ordinary feed-back control is not capable to give a satisfactory performance. Hence, the purpose of adaptive control is to give improvements, compared to ordinary feedback control or systems without feedback , in the sense of:

1) Counteracting the unpredictable changes in the system.
2) Adapting the system with regard to environmental conditions and with regard to variation of the class of input function.

2) Compensating partly for component failure.

## 1.3 Main Adaptive Techniques.

Adaptive control systems take many forms, three categories which appear to encompass a large proportion of them are :

1 - High gain technique

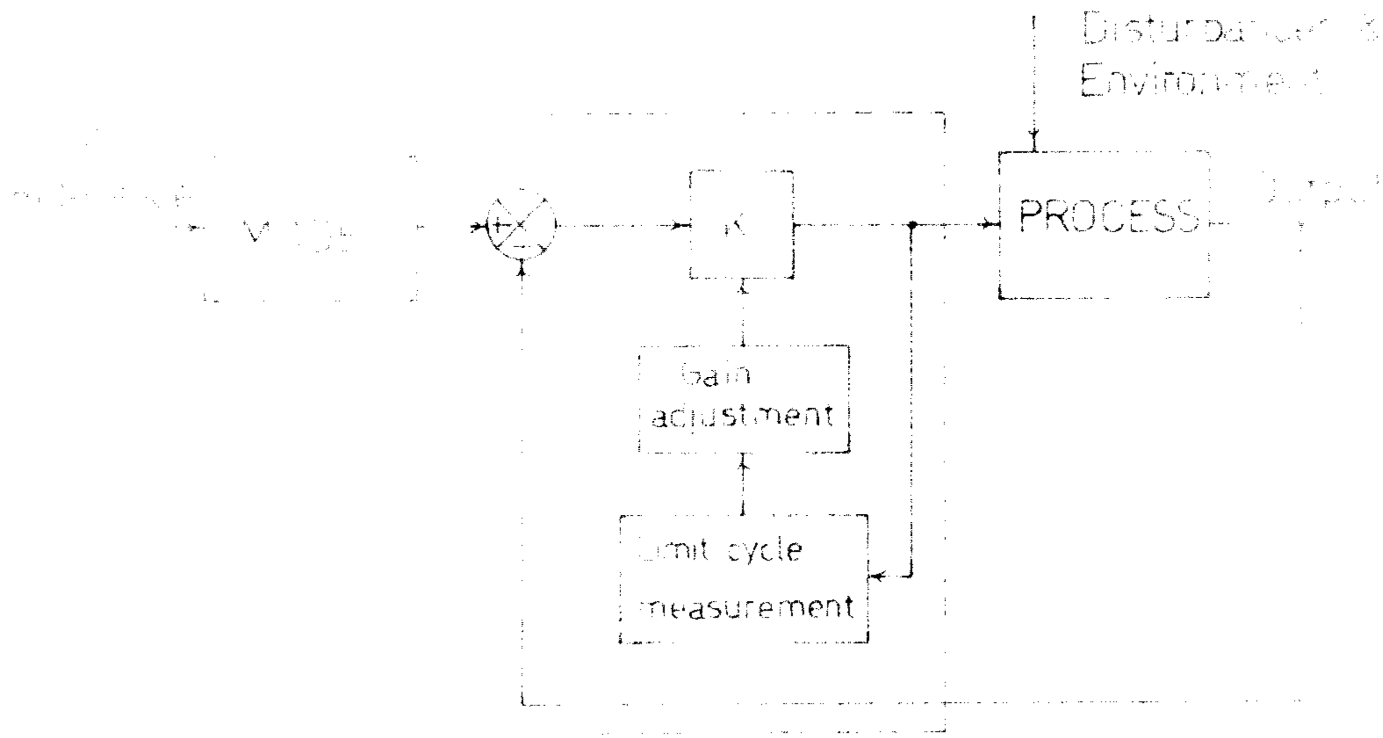
2 - Model reference technique

3 - Optimum adaptive technique

A particular version of each of these techniques will be considered and discussed briefly.

### 1.3.1 High gain technique (2,10).

A schematic diagram of the high gain technique is shown in fig. (1.1). The gain in the feedback loop around the changing process is kept as high as possible to keep the input-output transfer close to unity. Because stability problems arise at high gain, the signal in the loop is monitored to check for oscillations. With this information, the loop gain is adjusted to keep the system on the verge of instability. A response close to that of a particular model is obtained regardless of the process parameters by placing the model in front of the feedback loop. One of the objections



Disturbance &
Environment
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adjustment
Limit cycle
measurement

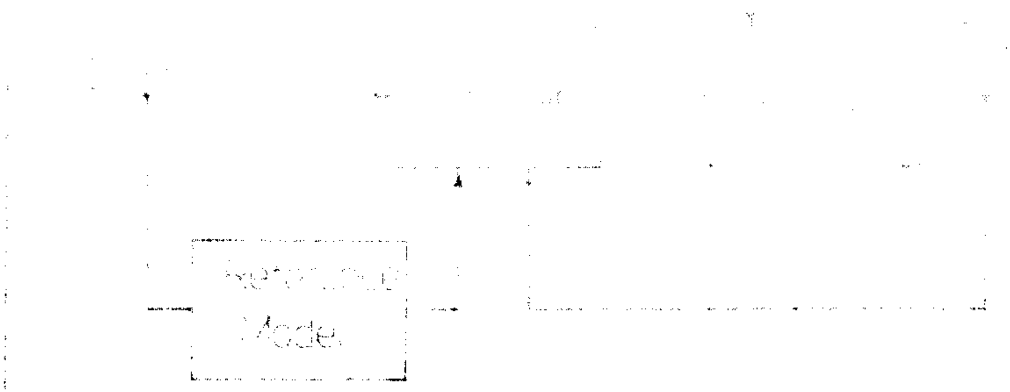
to this approach is that the designer [illegible] have a large amount of a priori information about the system.

### 1.3.2 Model-Reference technique .

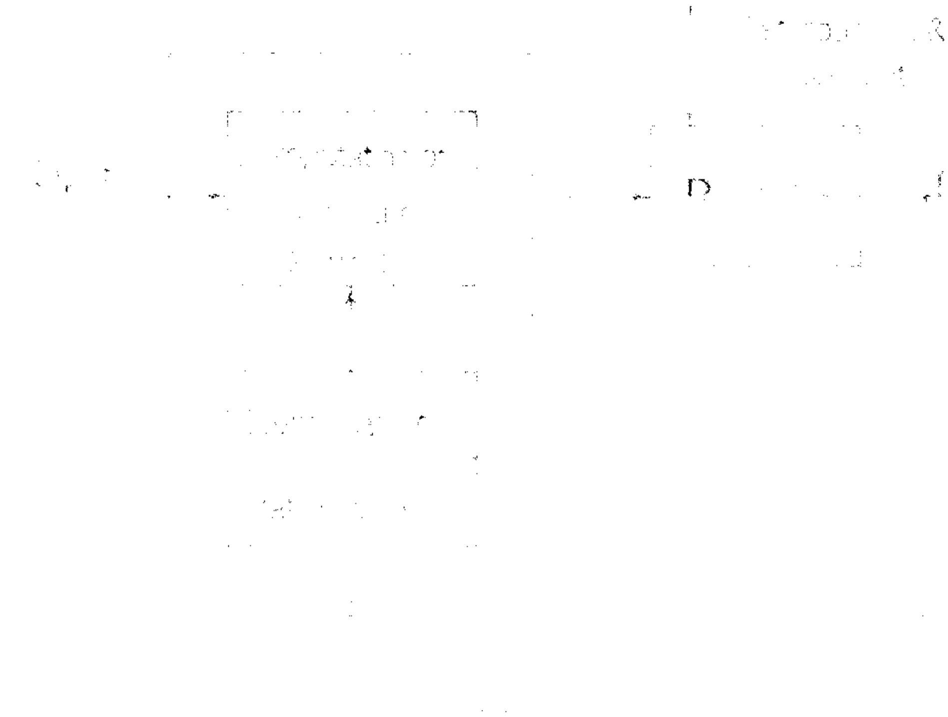
One of the general categories into which the broad scope of adaptive control systems may be subdivided is referred to as the model-reference adaptive technique. Fig.(1.2) shows a basic block diagram which encompasses most of the model reference adaptive control system configurations in which the reference model is explicit in the mechanization. The reference model is an analog representation of the desired dynamic response of the over all control system. The controller makes use of the output from the reference model together with the measurable outputs to generate a signal which compensates the effects of disturbances and environmental changes.

### 1.3.3 Optimal Adaptive Technique .

The optimal adaptive technique is the most general one. An optimum control law for the process is derived which is a function of both the state variables and the parameters of the system. Since the state variables are




Fig(1.?) Generalized model [illegible]



not generally accessible for measurement and are usually contaminated with noise, an estimator is necessary to give the best estime-in some sense - of the state variables based on measurements of the accessible outputs. Periodic identification of the process is also necessary to evaluate the system parameters and supply this information to the controller. Fig.(1.3) is a block diagram for an optimum adaptive system.

## 1.4 Organization of the Thesis.

The following chapters of the thesis will contain the following :

Chapter 2. Includes a survey of the main adaptive techniques: parameter adjustment, parameter perturbation, control signal augmentation, and other investigations into model-reference techniques.

In chapter (3) the design of model-reference adaptive systems via the second method of Lyapunov are considered. The different modifications introduced to get zero steady state error and speed the adaptation process are considered in detail.

In chapter (4) , a simulation study of a second-order adaptive system designed via the second method of Lyapunov is presented. Different forms of parameter variations are considered including sinusoidal and step variations. The effect of interaction between parameters is considered by carrying adaptation through the gain channel only and then through the gain and natural frequency channels simultaneously.

In chapter (5) a method is presented combining the merits of systems designed on the basis of an adaptive law and those designed for stability via the second method of Lyapunov.

Chapter (6) contains simulation results for systems designed on an adaptive law.

Chapter (7) is the conclusions.

# CHAPTER (2)

## REVIEW OF ADAPTIVE CONTROL TECHNIQUES

### 2.1 Preliminary.

A great deal of effort has been expended on the study of adaptive control techniques. This expenditure of effort has resulted in the conception of a wide variety of techniques. No attempt will be made in this chapter to survey all the different techniques devised in the past because several good survey articles are available[9,11]. However, due to the growing interest in the design of model-reference schemes in recent years. It will be considered here in detail.

### 2.2 Parameter Adjustment Techniques.

The philosophy of this technique is the indirect measurement of the varying parameters and then adjusting the controller parameters to compansate for these variations. Design objectives may be the minimization of a certain function of the error between the plant and model outputs or to design mainly for stability.

## [illegible] .1 [illegible] based on [illegible] law [12-1?].

The [illegible]djusting mechanism performs on automatic adjustment of the controller parameters so that :

$$\lim_{t \to \infty} ( \alpha_i - A_i ) = 0 \tag{2.1}$$

where $A_i$ are the model parameters and $\alpha_i$ are the corresponding system parameters. Hence $\alpha_i$ must continuously varying so that $\alpha_i = A_i$ .

The controller parameters may be adjusted to minimize some function of the error along a path of steepest descent [15]. The steepest descent law is given by :

$$\dot{\alpha}_i = - \lambda_i \frac{\partial f(\varepsilon)}{\partial \alpha_i} \tag{2.2}$$

where $\lambda_i$ are constants, and $f(\varepsilon)$ is the error function.

The error function is a very critical factor in the operation of the adaptive portion of the system, (i.e. the adjusting mechanism), and it may take the following forms.

$$f(\varepsilon) = \frac{1}{2} \left[ \sum_{i=0}^{n} q_i \frac{d^i \varepsilon}{dt^i} \right]^2 \tag{2.3-a}$$

or

$$f(\varepsilon) = \frac{1}{2} \sum_{i=0}^{n} q_i \left[ \frac{d^i \varepsilon}{dt^i} \right]^2 \tag{2.3-b}$$