A Thesis

Submitted to

The Department Of Electrical Engineering

For the Master Degree

In

Electrical Engineering

By

Mohamed Ali Abo Seaf

B.Sc. Electrical Engin.

Under the Supervision

Of

Prof. Dr. M.A.R.Ghonaimy

and Dr. M.A.Sheirah

Faculty of Engineering

Ain Shams University

June 1976

To Tarik

بسم الله الرحمن الرحيم

Summary of The Thesis

Presented by:

Eng. Mohamed Aly Abo Seaf.

For the Master Sc. Degree In

Electrical Engineering

Faculty of Engin. Ain Shams University

"Identification of physical Systems"

This thesis discusses three parameter identification algorithms developed maily for linear discrete-time dynamic system. They are namely, the stochastic gradient technique, the maximum likelihood method and the stochastic approximation method. The latter is the one Considered in great detail.

The stochastic approximation method was first presented in its generality and a variety of applications has demonstrated its usefulness in parameter identification and control of systems operating in a stochastic environment. Several variations of the stochastic approximation method were discussed to demonstrate different properties or speed of convergence and consistency of estimation.

A modified on-line second order stochastic approximation algorithm was then developed for the consistent identification of the unknown system parameters with parameter-estimate-dependent feedback control.

Using a known zero-mean white noise perturbation input, the algorithm was shown to converge in a mean square sense and with probability one to the true parameter values. It was found that the statistics of the disturbance and measurement noise need not be known for consistent identification. Other desirable features of the algorithm were its recursive form, rapid convergence and the computational ease of implementation.

Three examples, one fourth order and two second order linear discrete-time systems, were considered. A comparison of the first order stochastic approximation algorithm with and without learning, and the modified second order one has been performed. Also the stochastic approximation approach for adaptive control systems was considered. In this approach the coefficients of the pulse transfer function were estimated periodically by measuring the present and past values of the input and output for the controlled plant. Once these parameters were estimated they were used by a digital deadbeat controller, to compute the control signal. The effect of parameter variations and of perturbation signal level were studied.

Finally, the problem of reducing the order of the controlled plant was discussed.

ACKNOWLEDGMENT

The author greatly appreciates the valuable guidance and encouragement of Ass. Prof. Mohamed A.R. Ghonaimy, Electrical Department, Ain Shams University.

The author wishes to thank Dr. Mohamed A. Sheirah, Lecturer, Electrical Department, for supervising this research work.

Thanks are also for Dr. Aly Mettwally for his help during the writing of this thesis.

Finally, the author wishes to express his gratitude for the staff of the Voctational Training Department of the Armed Forces for Covering the Costs of the Computation time.

CONTENTS

Chapter 1

Introduction

The art of automatic Control is very old. It was developed, in its early stages, in an empirical fashion as an engineering solution to the problems of industry. World War II gave an impetus to the development of the theory and practice of automatic control. Systematic mathematical methods for analysis and design were developed and standarized to meet the urgent and constant military needs.

A typical classical control system uses a measuring device to measure the controlled variable which is compared with a desired one to obtain an error signal . This error signal operates on a series compensator to generate a control signal.

This control signal is used as an input to the actual process.

In general the design of a control system needs a complete set of information about the actual process. A mathematical model, using the physical properties of the process can be constructed.

Most of the pratical processes are subject to parameter variations , or distrubances which can be considered as parameter changes .

If the parameters of the process are changed frequently and with appreciable values, the performance of the controlled system, which is designed on the basis of the nominal values for these parameters will be inadequate. In this case a time varying model of the process must be obtained and a time varying controller, based on that model, must be used.

From the above discussion, it is evident that on-line identification is essential to obtain an optimal performance of the control system. However, on-line system identification must be achieved in the presence of the system normal operating signal and noise disturbances and that any systems tests, that have to be performed, must not distrub the normal operation of the system. Also the time taken to perform the identification must be relatively short otherwise the parameters of the system may be changed and a meaningless decision is made.

In general there is no exact solution to the problem. All the techniques which tackled the problem are trying to get the best estimate for the process model. Many techniques were suggested and theoritical studies were made, but only some of them more suitable for practical implementation.

Practically a simple model is enough to get a reasonable control with reasonable costs. For an optimal control, most of the techniques need perfect measurements and a large computer memory which may increase the cost of the system without corresponding return.

If an on-line identification technique is used, an optimal controller which can be adjusted periodically to compensate for the variation of the parameters, the system will be an adaptive system.

An adaptive control system is basically a feed back control system that automatically achieves a desired response in the presence of major changes in the parameters of the controlled plant and major extremal disturbances.

Adaptive control system will be tranformed to a self optimizing system, if an optimal controller which is based on the system states is used.

In most cases the states of the system are not available for measurements. Thus state estimation is needed. Fig.1.1 shows one of the modern versions of the self optimizing control system.

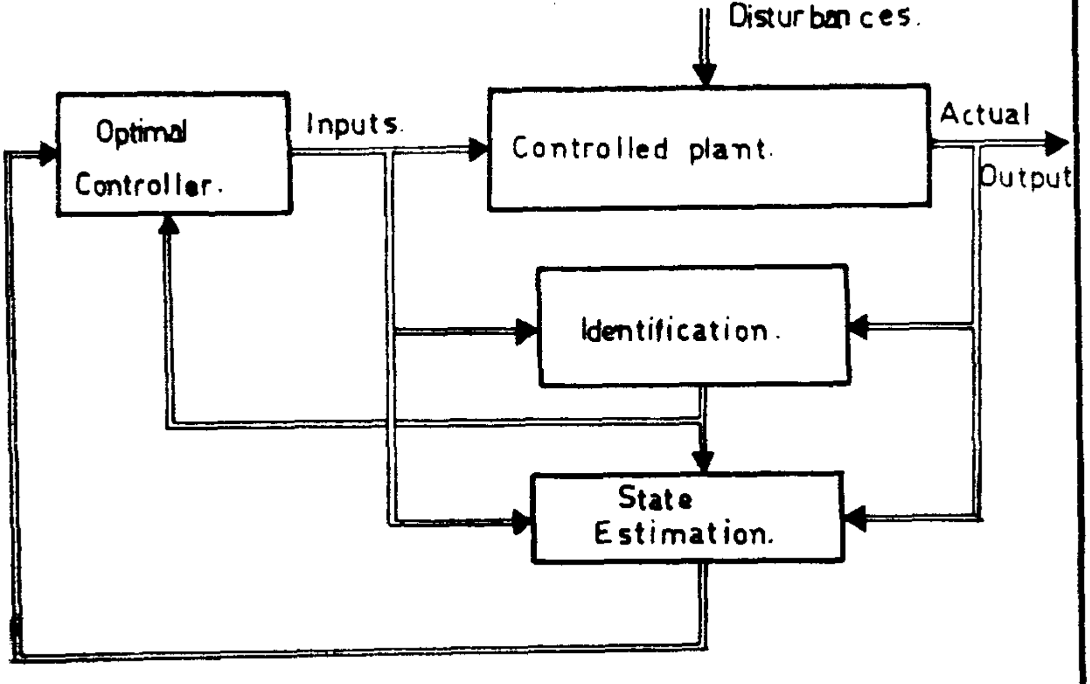

Fig 1:1 Self Optimizing Control System.

In this research work the identification problem is considered. A well-known stochastic approximation technique is considered and a detailed study of its properties is conducted. A modification to the second order stochastic approximation is developed, and better results are obtained.

The thesis is divided into five chapters.

Chapter 2 gives a review of some on-line identification techniques.

Chapter 3 illustrates the principal details of stochastic approximation and the identification techniques based upon it.

Chapter 4 demonstrates by the aid of three examples the the identification algorithms The computational results are presented and detailed discussion of the various effects are obtained.

Chapter 5 includes the important conclusions that are reached from this research work.

Chapter 2

Review of Some Methods For The Identification Of Process Parameters

2.1: Introduction:

There are many methods for the identification of physical processes. These methods can be classified, according to the type of model which results, in the following way :

- Nonparametric methods, which lead to nonparametric models, e.g. Fourier and correlation analysis
- Parametric methods, leading primarily to parametric models, such as parameter estimation methods.

Within each class many different identification methods are known.

In this chapter a brief acount will be given for only two methods concerned with the determination of the process difference equation coefficients.

The two techniques, maximum likelihood (M.L.), and stochastic gradient (S.G.), are chosen here for the following reasons:

- S.G. technique falls within the broad framework of stochastic approximation with which we are concerned in this research work.
- S.G. requires a priori knowledge of noise statistics. If this information is not available, the M.L. technique can be applied to estimate such information.
- The M.L. is applicable to multiple output systems involving disturbances in the input and the output, where the statistics of the disturbances are unknown.
- The method of M.L. is shown to produce estimators for which the amount of computation is prohibitive but which these estimators are used as a standard against which the accuracy of more easily computed methods, such as stochastic approximation, may be judged.

2.2: Statement of the identification Problem :

Consider a linear discrete-time invariant parameter system represented by an n-th order finite difference equation as :

$$\begin{aligned} y(k) = & -a_1 y(k-1) - a_2 y(k-2) - \dots - a_n y(k-n) \\ & + b_1 u(k-1) + b_2 u(k-2) + \dots + b_n u(k-n) \\ & + d_1 v(k-1) + d_2 v(k-2) + \dots + d_n v(k-n) \end{aligned} \qquad (2.2\text{-}1)$$