AN ANALOG COMPUTER STUDY OF CONTROL SYSTEM ADAPTATION USING CROSSCORRELATORS AND REFERENCE MODELS

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ABSTRACT

The fact that the autocorrelation of white noise is a delta function forms the basis for identification of a lumped, linear system with slowly time-varying parameters. By crosscorrelating between low level injected noise and the process output, the continuous impulse response function is approximated by a finite number of samples. All system parameters are then computed and processed to adjust a controller such that the desired overall transfer function is approached. A model reference technique is examined for a system characterized by a variable gain and variable pole. Analog computer studies are made for a first and second order system.

PREFACE

An adaptive control system is essentially a feedback control system capable of adjusting its characteristics in a changing environment so as to operate in an optimum manner according to some specified criterion. Chapters 1 to 3 provide some background information on the general concept of adaptation in engineering control systems.

Identification of the impulse response function of a lumped, linear, slowly time-varying system is achieved in Chapter 4 by crosscorrelating the system output with the test noise. The generation of possible performance indices from the identification results is illustrated in Chapter 5. Chapter 6 investigates a technique for computing the system parameters from a finite number of impulse response samples, for computing the required controller gains, and for compensation such that the overall transfer function approaches the desired transfer function.

A model reference technique applicable to systems characterized by a variable gain and variable pole is examined in Chapter 7 as a possible alternative to adaptation by crosscorrelation.

Simulation studies are conducted on the TR 48 analog computer.

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CHAPTER 1

INTRODUCTION

Control system theory deals with the problem of how to elicit, from a given physical plant, outputs which are considered particularly desirable by adding a suitable auxiliary device, generally designated as compensator. The term "adaptation" has been taken from the biological sciences to denote a type of optimization procedure in engineering control systems. Adaptation consists in a more or less gradual change of certain properties of biological systems in response to changes in the environment aimed at the improvement of the behavior with respect to the environment.[1*]

In a self-optimizing, or adaptive control system, the designer, rather than organize the system to meet anticipated inputs and parameter variations, provides the system with a means of continuously monitoring its own performance relative to a specified index of performance. The system organizes itself by modifying its own parameters by closed-loop action so as to approach the optimum condition.

For systems whose characteristics change over a wide range as a function of such environmental variables as pressure, temperature, humidity, speed, or altitude, "passive" adaptation, conventionally realized through a feedback signal, may be inadequate in meeting performance specifications.[2]

To place adaptation by white noise crosscorrelation and reference models into proper perspective, a brief description of the structure of a general adaptive control system is first provided in Chapter 2. Criteria for classifying adaptive systems are enumerated in Chapter 3.

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*Superscripts refer to the references listed in the bibliography.

CHAPTER 2

ELEMENTS OF A GENERAL ADAPTIVE CONTROL SYSTEM

A general adaptive control system consists essentially of five elements: plant, identification, adaptation guides, decision, and modification. Fig. 2.1 p. 3 shows a system which incorporates simultaneously all five elements.[3] In a practical system, some elements may be combined, simplified, or omitted entirely.

2.1. PLANT.

The plant is the physical system to be controlled.

2.2. IDENTIFICATION.

2.2.1. Process Identification.

Process Identification establishes the relationship between the input and output of a plant. It must generally be made in the presence of normal operating signals and noise disturbances. Any tests performed upon the plant must not unduly disturb the normal operation of the system. Consequently, neither direct application of an impulse or step function, nor removal of the plant from operation during the test is permissible.

It is also essential that the identification time be relatively short with respect to the rate of variation of the plant parameters if the identification results are to be useful for the decision-making and modification phases of the adaptive process.[4]

Identification schemes depend upon the particular adaptive problem. Some representative variations are:

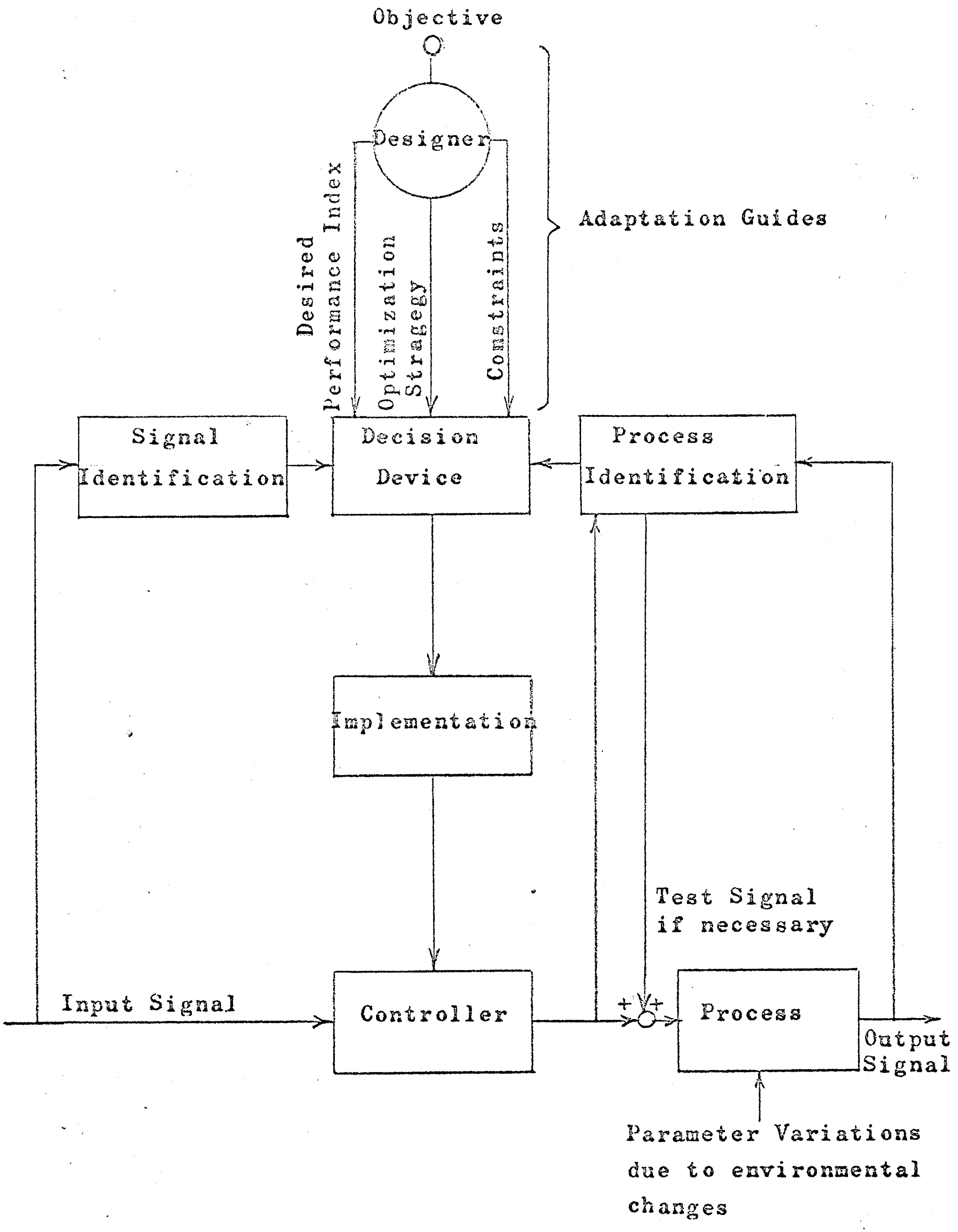

Fig. 2.1. Structure of a General Adaptive Control System.

(a) It may be total, i.e., the impulse response function $w(t)$ or the transfer function $W(s)$; it may be partial, e.g., the damping factor of the dominant poles.

(b) It may be for the process alone or for the overall control system.

(c) Identification may require the insertion of a test signal either periodically or only during intervals when the normal actuating signal is small.

(d) Only the deviation of the process from a model may be desired as an indirect measure of the process dynamics.

2.2.2. Signal Identification.

A frequent or continuing evaluation of signal properties may provide information for the selection of performance or optimization criteria for the control system.

2.3. ADAPTATION GUIDES.[5]

2.3.1. Objective.

The objective of adaptation may be, for example, to operate a system at minimum cost or to maximize the efficiency of operation.

2.3.2. Index of Performance.

Analytically, system performance may be described by such characteristics as frequency response, transient response, poles and zeros, differential equations, or state variables. System performance is generally specified by some descriptive parameters of the system response, such as bandwidth, rise time, overshoot, or settling time. Engineering specifications are seldom expressable by an exact analytical function.