EEE 555 ADAPTIVE CONTROL STRATEGIES

LECTURE 1

INTRODUCTION

INTRODUCTION TO THE COURSE

Course code: EEE 555
Course title: Adaptive Control Strategies

- Instructor: Dr. Tolgay Kara, kara@gantep.edu.tr
- Main text: Åström, Karl J., and Björn Wittenmark. *Adaptive control*. Courier Corporation, 2013.
- Lectures: Tuesday 9.25
- Office hour: Monday 14.00-15.00
- Grading: Midterm exams (25%), Final exam (50%)
- Attendance: 70% required.

WHAT IS ADAPTIVE CONTROL?

An adaptive controller is a controller that can modify its behaviour in response to variations in process dynamics or disturbance characteristics.

A feedback control system aims to control a process at the desired set value or predefined action pattern despite the effects of internal and external disturbances.

Question 1: What is the difference between ordinary feedback and adaptive control?

Question 2: Why and when do we need an adaptive system instead of ordinary feedback?

WHAT IS ADAPTIVE CONTROL?

Although all control systems that have variable behaviour in accordance with process or disturbance variations can be called adaptive, we generally prefer to define an adaptive controller as “a controller with adjustable parameters and a mechanism to adjust the parameters”.

In this sense, what we call adaptive control in the context of this course is *control with parameter adaptation.*

WHAT IS ADAPTIVE CONTROL?

Adaptive control has two loops, one for the mechanism to adjust the parameters of the controller (which is the “parameter adjustment loop”), and one for the feedback control of the process variable of concern (which is the “feedback loop”).

WHAT IS ADAPTIVE CONTROL?

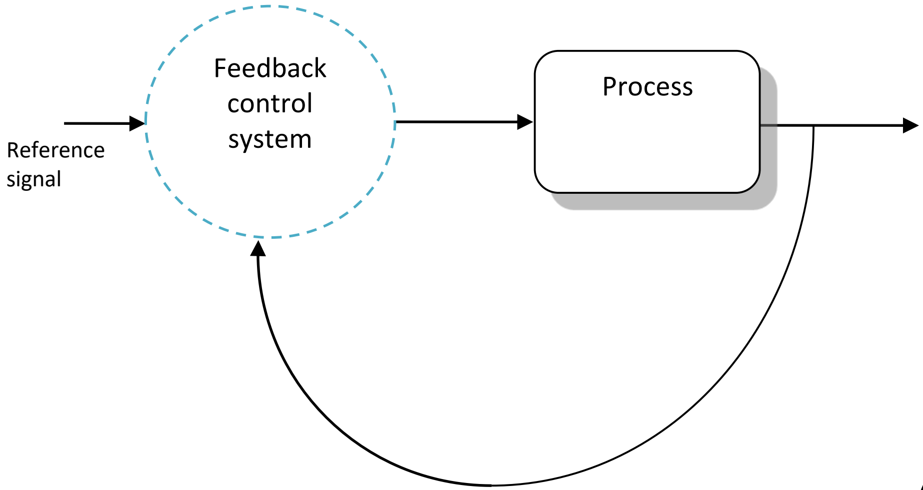


Figure 1.1 Feedback Control Diagram

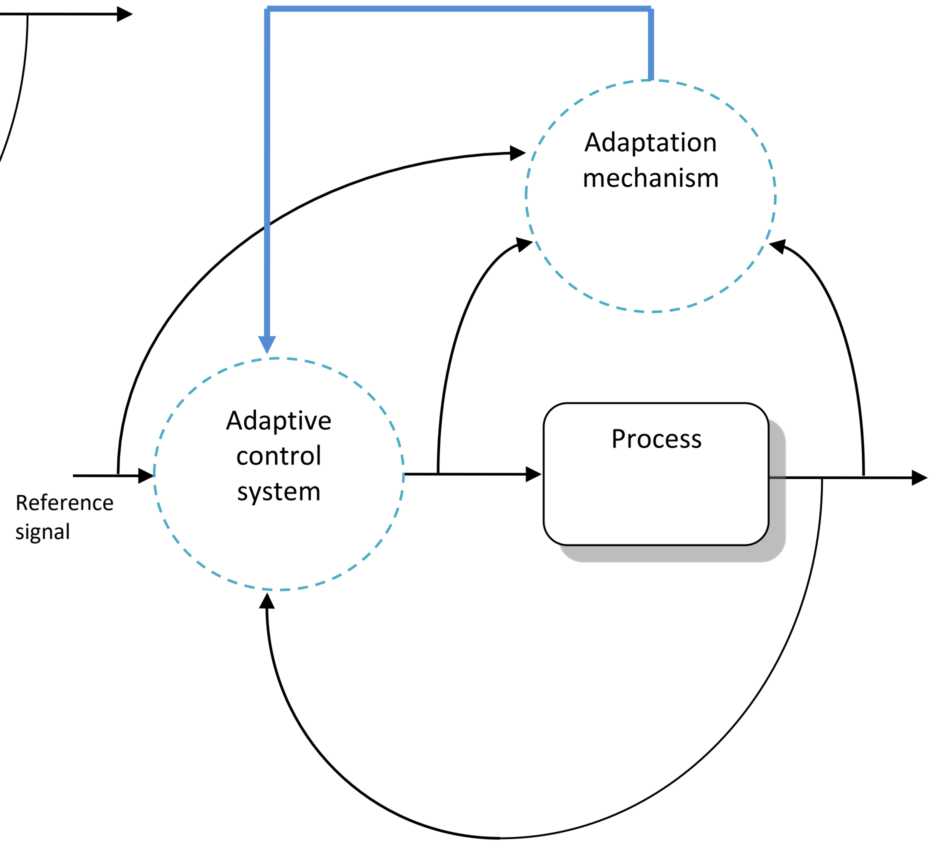


Figure 1.2 Adaptive Control Diagram

FEEDBACK VERSUS ADAPTATION

- A conventional feedback control system is mainly dedicated to the *elimination of the effect of disturbances upon the controlled v*ariables.
- An adaptive control system is mainly dedicated to the *elimination of the effect of parameter disturbances (variations) upon the* performance of the control system.

FEEDBACK VERSUS ADAPTATION

Feedback control

- Has a single loop for control of process variable
- Can cope with controlled variable variations
- Useful in rejecting disturbances acting upon controlled variable
- Measurement of the controlled variable is used to generate the loop signal

Adaptive control

- Has two loops for control and parameter adaptation
- Can cope with process and disturbance variations
- Useful in rejecting disturbances acting upon process parameters
- Measurement of a performance index is used to generate parameter updates

EVOLUTION OF ADAPTIVE CONTROL

- Mid 1950s: Flight control systems (eventually solved by gain scheduling)
- 1957: Bellman develops dynamic programming
- 1958: Kalman develops the self-optimizing controller “which adjusts itself automatically to control an arbitrary dynamic process”
- 1960: Feldbaum develops the dual controller in which the control action serves a dual purpose as it is “directing as well as investigating”

EVOLUTION OF ADAPTIVE CONTROL

- Mid 60s-early 70s: Model reference adaptive systems
- Late 60s-early 70s: System identification approach with recursive least-squares
- Early 1980s: Convergence and stability analysis
- Mid 1980s: Robustness analysis
- 1990s: Multimodel adaptive control, Iterative control
- 2000s: L1 adaptive control: fast adaptation with guaranteed robustness.

WHY ADAPTIVE CONTROL?

- High performance control systems may require precise tuning of the controller but plant (disturbance) model parameters may be unknown or time-varying
- “Adaptive Control” techniques provide a systematic approach for automatic on-line tuning of controller parameters
- “Adaptive Control” techniques can be viewed as approximations of some nonlinear stochastic control problems (not solvable in practice)
- Objective of “Adaptive Control”: *to achieve and to maintain acceptable level of performance when plant (disturbance) model parameters are unknown or vary*

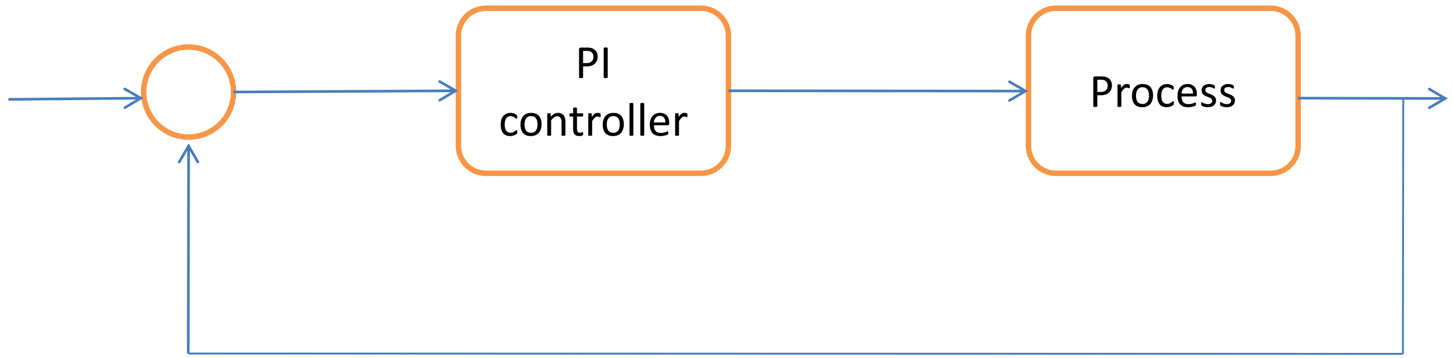
WHY ADAPTIVE CONTROL?

We may need adaptive control in the following special cases, where ordinary feedback does not compensate for the process variations:

- Nonlinear actuators
- Flow and speed variations
- Flight control
- Variations in disturbance characteristics

WHY ADAPTIVE CONTROL?

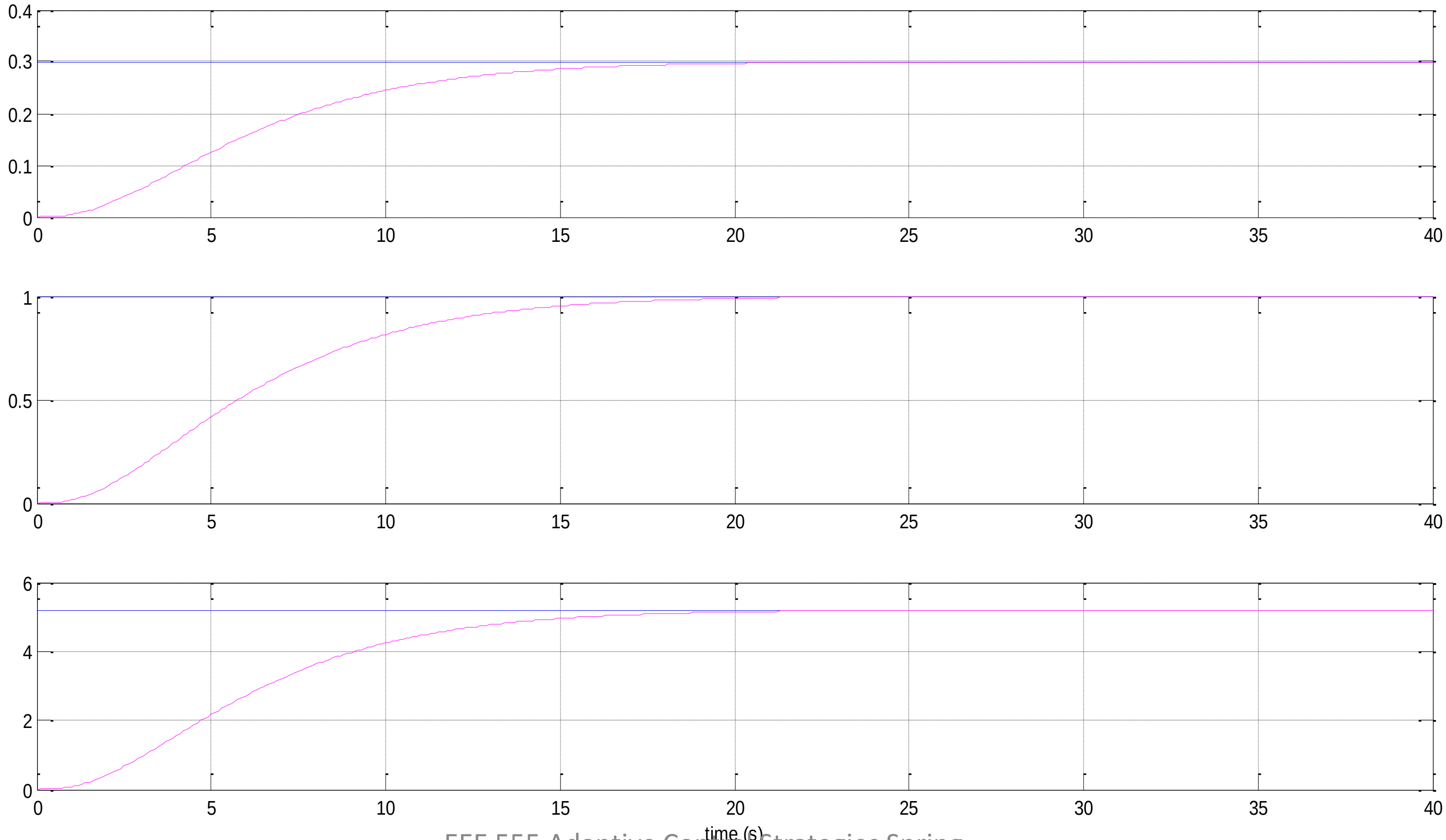
- Nonlinear actuators



- Controller has gain 0.15 and reset time 1. and process has transfer function $G_p(s)=1/(s+1)^3$

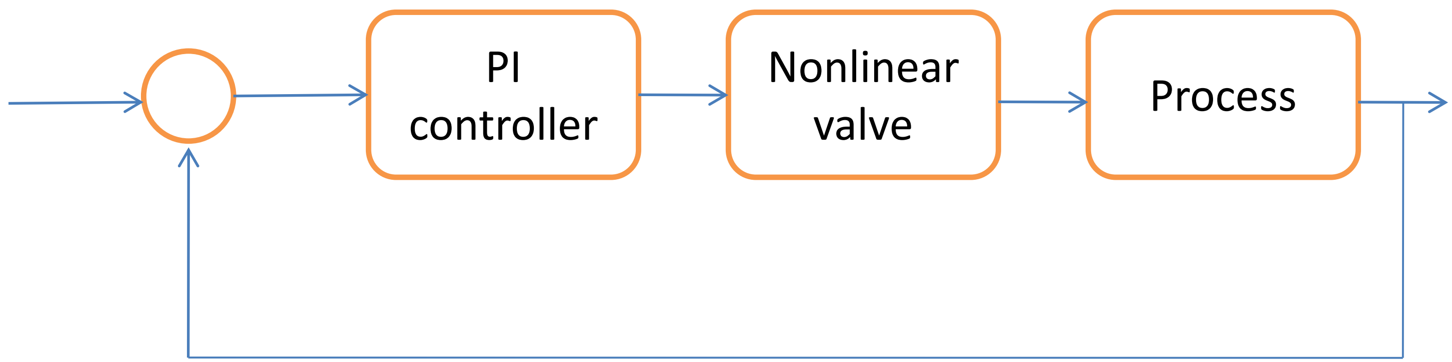
WHY ADAPTIVE CONTROL?

- Nonlinear actuators



WHY ADAPTIVE CONTROL?

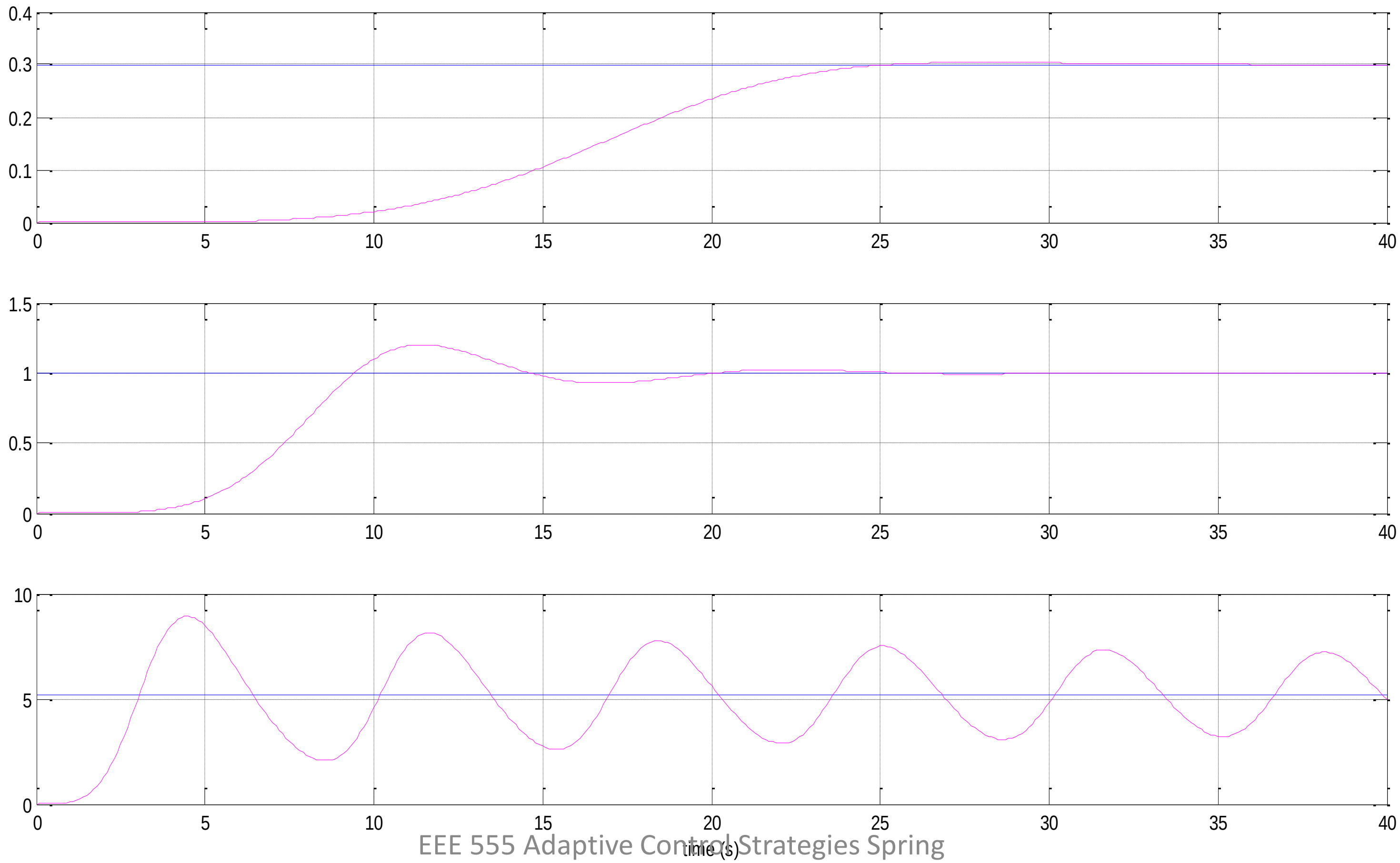
- Nonlinear actuators



- Controller has gain 0.15 and reset time 1. Nonlinearity is $f(u)=u^4$ and process has transfer function $G_p(s)=1/(s+1)^3$

WHY ADAPTIVE CONTROL?

- Nonlinear actuators



METHODS OF IMPLEMENTING ADAPTIVE CONTROL

Adaptive controllers can be designed according to the application area in two ways:

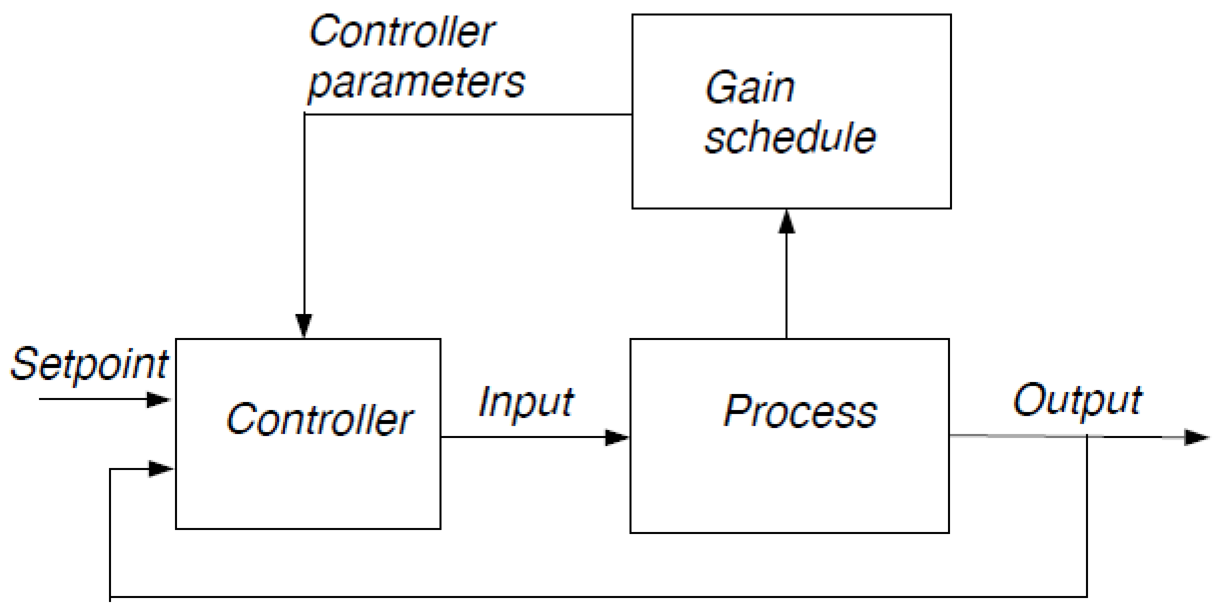
- General purpose adaptive controllers, which fulfill the requirements of a general process control system like wide range of applicability, robustness, offset free operation, reasonable complexity in hardware and software, simplicity in start-up.
- Dedicated adaptive controllers, which rely on a priori knowledge about the process and have special application areas like linearizing controllers or robot control.

METHODS OF IMPLEMENTING ADAPTIVE CONTROL

Essentially there are four methods to implement adaptive control

- Gain scheduling control
- Model reference adaptive control
- Self-tuning control
- Dual control

GAIN SCHEDULING CONTROL



GAIN SCHEDULING CONTROL

In many cases, process dynamics change with operating conditions in a known fashion, e.g.

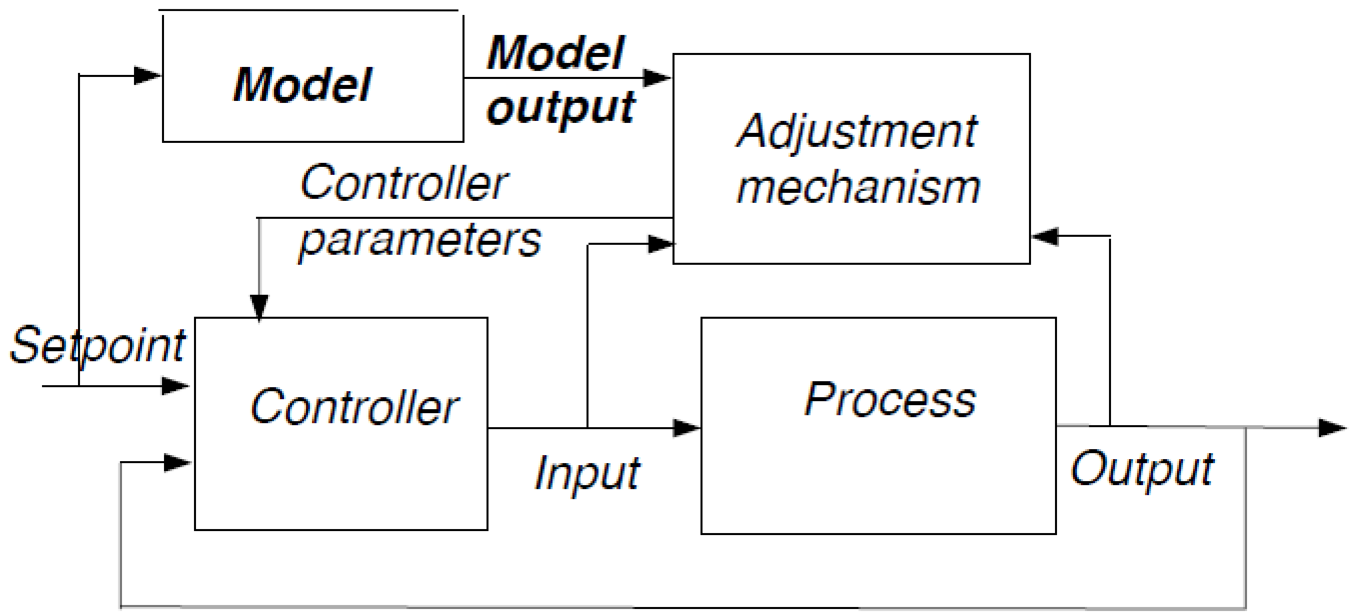
– Flight control systems

– Compensation for production rate changes

– Compensation for paper machine speed

Controller parameters change in a predetermined fashion with the operating conditions

MODEL REFERENCE ADAPTIVE CONTROL



MODEL REFERENCE ADAPTIVE CONTROL

- *Plant has a known structure but the parameters are unknown*
- *Reference model specifies the ideal (desired) response to the external command (reference signal)*
- *Controller is parameterized and provides tracking*
- *Adaptation is used to adjust parameters in the control law*

SELF-TUNING CONTROL

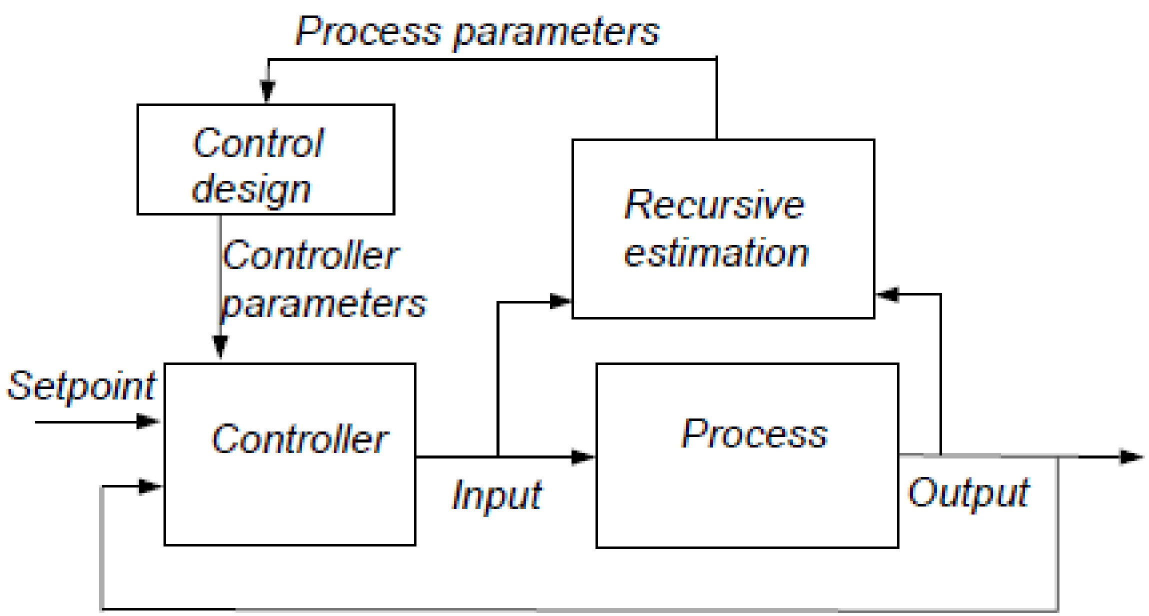


Figure 1.3 Self-tuning Control System Diagram

SELF-TUNING CONTROL

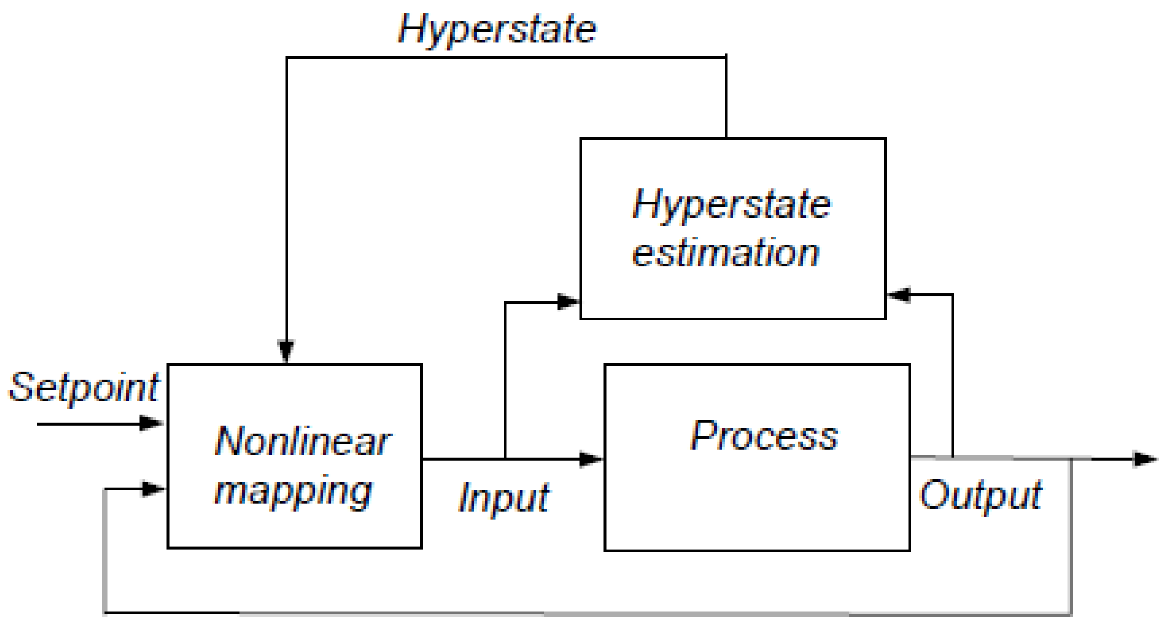
Model-based tuning consists of two operations:

– Model building via identification

– Controller design using the identified model

Self-tuning control can be thought of as an automation of this procedure when these two operations are performed on-line

DUAL CONTROL



DUAL CONTROL

Use of nonlinear stochastic control theory to derive an adaptive controller

No distinction between parameters and state variables

The controller is a nonlinear mapping from the hyperstate to the control variable

Can handle very rapid parameter changes

Unfortunately solution is very hard or impossible to obtain for most systems

NEXT WEEK

Gain Scheduling Control