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ScienceDirect

Journal of Electrical Systems and Information Technology 1 (2014) 1–9

www.elsevier.com/locate/jesit

State-of-the-art in control engineering

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Available online 12 March 2014

Abstract

The paper deals with new trends in research, development and applications of advanced control methods and structures based on the principles of optimality, robustness and intelligence. Present trends in the complex process control design demand an increasing degree of integration of numerical mathematics, control engineering methods, new control structures based of distribution, embedded network control structure and new information and communication technologies. Furthermore, increasing problems with interactions, process non-linearities, operating constraints, time delays, uncertainties, and significant dead-times consequently lead to the necessity to develop more sophisticated control strategies. Advanced control methods and new distributed embedded control structures represent the most effective tools for realizing high performance of many technological processes. Main ideas covered in this paper are motivated namely by the development of new advanced control engineering methods (predictive, hybrid predictive, optimal, adaptive, robust, fuzzy logic, and neural network) and new possibilities of their SW and HW realizations and successful implementation in industry.

Keywords: PID control; Predictive control; Optimal control; Adaptive control; Self-tuning control; Fuzzy and neural control; Genetic algorithms; Embedded control systems; Information and communication technologies

1. Introduction

Automatic control is crucial for practically all engineering activities. Automation technology (Frank, 1999) is understood to be the use of such methods, control strategies, processes, and installations (hardware and software) which are capable of fulfilling defined objectives without the constant interference of man in a largely independent manner, i.e., automatically. Motivated by the practical success of conventional control engineering methods in consumer products and industrial process control, there has been an increasing amount of work on development of new methods which are based on new optimization techniques, soft computing strategies, and effective hardware realization of control algorithms. Process control continues to be a vital, important field with significant unresolved research problems and challenging industrial applications. Automatic control methods with integration of information and communication systems are today pervasive in all fields of people's activities. The research, development and implementation of new control

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Peer review under responsibility of Electronics Research Institute (ERI).

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jesit.2014.03.002

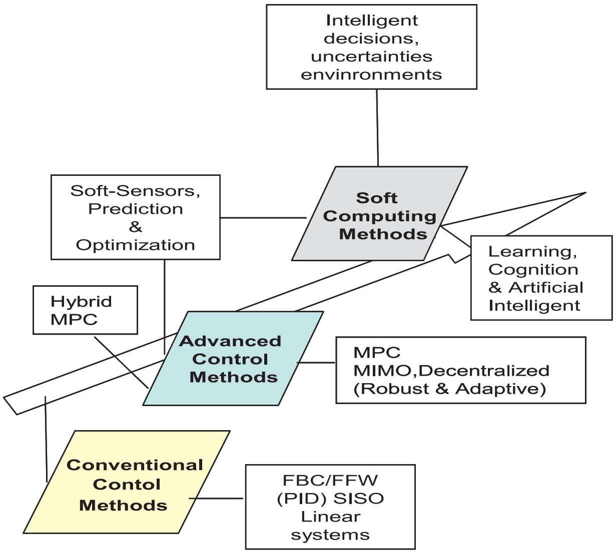

Fig. 1. Trends in development of control engineering methods.

principles in automation field have been very dynamic (Fig. 1). Applications of automatic control principles and control methods appear practically everywhere in consumer electronics, homes devices, in all types of industry, communications systems, modern types of vehicles, mechatronics, bank sector, health services, etc. Methods of automatic control were recognized as a very powerful technique applicable to many problems in diverse fields.

2. Development of control engineering methods and structures

Today we can recognize four stages of the control engineering methods development (Table 1). Conventional control strategies (*Category A*) have been widely used in industry for several decades. Tuning of these controllers can be realized manually or automatically. Manual control principles are used in many industrial processes as a effective decision tool or as a supervisory control in extraordinary situation or for manually adjusted of process and controller parameters.

In many cases of manual process control, the process operator adjusts process and controller parameters on the base of own experiences. The vast majority of automatic control loops in the process industries (90%) still rely on various forms of the ubiquitous PID controller (*Category A* in Table 1) which has been commercially available for over 70

Table 1
Time development control engineering methods.

A. Conventional PID Control	B. Advanced Control I	C. Advanced Control II	D. Advanced Control III
Manual Control	Adaptive and Selftuning Control	Optimal Control Methods (LQ and LQG)	Hybrid Predictive Control
Feedback Control (FB)	Gain Scheduling Method	Robust Control Methods (H_2, Hinf, IMC)	Fuzzy Control (PID, MPC FPGA)
Cascade Control (CC)	Multivariable Control Methods (State Space and Transfer Functions Models)	Model Predictive Control (MPC-DMC, MPC-GPC)	Neural Network Control (Optimal, MPC, FPGA)
Feedforward Control (FFW)	Multivariable Control Methods (Decoupling and Decentralized Control)	Decentralized Control (Time domain, Frequency domain)	Discrete Events Control (Hybrid with Petri nets)
Ratio Control (RC)	Pole Placement Methods (SISO, MIMO)	Algebraic Control Methods (Polynomial Synthesis)	Nonlinear Hybrid Soft Computing Control
Comb. Control Structures (FB + FFW + CC)	Nonlinear Control Methods (I/O linearization)	Robust QFT Control Methods	Expert Control Methods