Chapter 7
Evolutionary Control Systems

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ABSTRACT

In control systems, the actual output is compared with the desired value so a corrective action maintains an established behavior. The industrial controller most widely used is the proportional integral derivative (PID). For PIDs, the process is represented in a transfer function. The linear quadratic regulator (LQR) controller needs a state space model. The process behavior depends on the setting of the controller parameters. Current trends in estimating those parameters optimize an integral performance criterion. In this chapter, a unified tuning method for controllers is presented, the evolutionary algorithm MAGO optimizes the parameters of several controllers minimizing the ITAE index, applied on benchmark plants, operating on servo and regulator modes, and representing the system in both transfer functions and differential equation systems. The evolutionary approach gets a better overall performance comparing with traditional methods. The evolutionary method is indeed better than the classical, eliminating the uncertainty in the controller parameters. Better results are yielded with MAGO algorithm than with optimal PID, optimal-robust PID, and LQR.

INTRODUCTION

Optimal control is a branch of modern control theory (Hull, 2003) that focuses on those properties of the control strategies that provide solutions to problems by minimizing an objective function, or otherwise, a function depending on the

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performance of a system variable. Those indices or performance functions may include a measurement error, the control effort or some other important characteristic from the control system; performance indices most commonly used in control loops are IAE, ITAE, IE and ISE (Åström and Hägglund, 1995). So, when minimizing some of these performance indices in conjunction with the controllers tuning, is a situation that can be formulated as an optimization case. A problem with this approach is that the controller and the plant are loosely coupled, yielding multiple kinds of uncertainty. Addressing this uncertainty, when tuning optimal controllers via an evolutionary algorithm, is one of the purposes of this Chapter.

One of the trends in the tuning of controllers is the use of Evolutionary Algorithms (EA) to determine the optimal parameters of the controller. EA have been used in various fields of engineering (Fleming and Purshouse, 2002), LQR tuning (Ghoreishi et al., 2011; Tijani et al, 2013; Hassani 2014), drivers in tuning PID controllers (Li et al., 2006; Hernández-Riveros et al, 2014), showing successful solutions in each case applied. It has been found in the literature reviewing that EA are applied to the tuning of controllers on particular cases and not in the general cases, as in this chapter. Nor are compared with traditional methods that minimize some tuning performance index (Chang & Yan, 2004; Fan & Joo, 2009; Junli et all, 2011; Saad et al, 2012a; Saad et al, 2012b). There are alternatives to the traditional rules of tuning, but there is not yet a study showing that the use of heuristic algorithms it is indeed better than using the traditional rules of optimal tuning. Hence, this matter is addressed.

EA are widely studied as a heuristic tool for solving nonlinear systems, continuous, discontinuous, convex and not convex optimization problems where traditional methods are not effective, and in many cases, to support successful solutions. EA are based on biological or natural principles for the study and design of human-made systems (Yu and Gen, 2010), such as the theory of natural selection (Darwin, 1859), heredity (Ayala and Kiger, 1984) and population genetics (Fisher, 1930).

In this chapter, the use of the evolutionary algorithm MAGO (Hernández and Ospina, 2010) as a tool to minimize a characteristic performance index in a control loop to thereby obtaining optimal values of the controller parameters is presented.

MAGO (Multi dynamics Algorithm for Global Optimization) works with statistics from the evolution of the population (Hernandez and Ospina, 2010). MAGO is a heuristic algorithm resulting from the combination of multidimensional unconstrained optimization without derivatives, Statistical Control and Estimation of Distribution. MAGO has shown to be an efficient and effective tool to solve problems whose search space is complex (Hernandez and Villada, 2012) and works with a real-valued representation. Additionally, MAGO only requires two parameters provided by the analyst: the number of generations and the population size; features that facilitate