Genetic Search of Block-Based Structures of Dynamical Process Models

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Abstract. Genetic identification of models of dynamical systems is becoming a well established research field. Nowadays it is hard to obtain more precise numerical results than state of the art methods, but, in our opinion, there is still room to improve the understandability of genetically induced models. In this paper it is proposed a method that focuses in the comprehensibility of the final model, while keeping most of the numerical precision of former studies.

The main innovation in this work is centered in the concept of “understandable” system. We do not use state space designed, rule based models, but z-transform based models, comprising linear, discrete dynamical models of first or second order and memoriless nonlinear elements (saturation, dead zone or other nonlinear gains.) This way, we provide control engineers with their preferred representation in moderate to complex models, and facilitate the task of designing control systems for these processes.

Keywords: Block-based models, Process control, GA-P algorithms, System Identification.

1 Introduction

Genetic identification of models of dynamical systems is becoming a mature research field. It is widely admitted than both GA and GP can find very precise representations of dynamical models. But the use of the structures found with GP algorithms is not very extended in practice. This is mostly due to the complexity of the final output: the output of canonical GP, even in simple nonlinear models [7] is hard to interpret, and not very different in complexity from a neural network.

The comprehensibility of a model of a dynamical system has also been studied under different perspectives. In our opinion, the most advanced methods have been developed in the fuzzy community (see, for instance [2]). Genetic Fuzzy systems are able to produce a set of linguistically understandable fuzzy rules that define the state-space behavior of a dynamical system. Fuzzy models have important advantages over black-box models like the formerly mentioned neural networks, or least-square fitted polynomials. But there are many circumstances in which control engineers are not comfortable with a state space, rule based
description of a dynamical model. According to our own experience, many control systems are best designed in the classical framework (z transform). The preferred output for a small to moderately complex dynamical model is a block-based structure where blocks are either

- A linear, discrete dynamical model of first or second order.
- A memoriless nonlinear element (saturation, dead zone or other nonlinear gain).

In fact, there are preliminary works in GP in which is used an structure with certain similarities to the one being proposed herein [8, 9]. But the work in this field, up to our knowledge, was not continued. In this paper we propose to use more modern hybrid genetic techniques than those used in these preliminary works and to improve both numerical properties and the quality of the block based representation. Our objective is to produce models with a high linguistic quality, and to promote their practical use.

1.1 Structure of the Paper

The outline of this paper is as follows: in Sect. 2, different genetic-based models of dynamical systems are discussed. In Sect. 3 the algorithm proposed here is described. Then (Sect. 4) an experimental validation of our proposal is done, modeling both a synthetic and a real process and comparing the results with those obtained with previous works. The paper finishes (Sect. 5) with the concluding remarks and future work.

2 Genetic-based comprehensible models

Most of the evolutionary methods for system identification from sampled data focus in nonlinear state space-based models. For this kind of models, the objective of the learning process is the production of a set of difference equations defining the dynamics of the process. Unfortunately, for practical purposes, a set of equations that relates all state variables between them is hard to manage in all but small sized problems. Modular representations are usually preferred, because they allow to determine groups of variables affected by specific parameters.

Genetic Programming has been applied to learn such modular models. One of the first examples was given in [6], where a structured Genetic Algorithm, in a tree based representation, is used. The set of functions that was proposed contained only two-input quadratic functions, which are not the building blocks that control engineers expect to find in structured models. Some implementations nearer to usual practice can be found in [3, 7] and other, less common approaches to model the dynamics of a system, are described in [4]. Most of these schemes introduce dynamic considerations by means of extended terminal sets, that include either input and input-output delayed variables.

One of the most complete methods is described in SMOG [8, 9]. The problem is addressed there as a search of a diagram block based representation of a