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Applied Mathematical Modelling 29 (2005) 565–578
APPLIED MATHEMATICAL MODELLING
www.elsevier.com/locate/apm

Order reduction of linear discrete systems using a genetic algorithm

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Received 1 September 2003; received in revised form 1 July 2004; accepted 6 September 2004
Available online 13 December 2004

Abstract

Order reduction of linear discrete systems using classical methods of optimization is well understood and developed by various workers. The present effort is towards development of a method of linear discrete system order reduction using a genetic algorithm (GA) to get rid of usual difficulties of classical methods. The method developed is applied to a variety of systems and the reduced order models are obtained using the method. The results reported are encouraging and more work can be initiated in this area using a GA.
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Keywords: Order reduction; Discrete; Genetic algorithm

1. Introduction

While mathematically modeling a real life system in the area of engineering, a complex high order model of the system under consideration is obtained from theoretical considerations. But this complexity often makes it difficult to understand the system behavior. To ease this situation, preliminary design and optimization of such systems are done using a low order model (LOM) of the original high order system (OHOS), such that the LOM represents the OHOS with all its

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doi:10.1016/j.apm.2004.09.016

salient features. A large number of methods exist for obtaining a LOM from an OHOS, but the methods using response error minimization occupy a premier position among them.

Now order reduction of linear systems using step and impulse response matching involves the error minimization problem which has been handled with classical techniques so far by different workers [2,5,6]. But all these suffer from the limitations of classical techniques.

There are some common difficulties with most of the classical techniques using traditional direct and gradient-based search and optimization approaches as given below:

1. Dependency on the initial point chosen for the convergence to an optimal solution.
2. Global solution not necessarily found out.
3. An algorithm efficient in solving one search and optimization problem may not be efficient in solving a different problem.
4. Algorithms are not efficient in handling problems having discrete variables.

Due to nonlinearities and complex interactions among problem variables often exist in complex search and optimization problems, the search space may have many optimal solutions, of which most are locally optimal solutions, having inferior objective function values. When solving these problems, if traditional methods get attracted to any of locally optimal solutions, there is no escape from it and hence is a major limitation of classical techniques [7].

Because of all these reasons, a number of search and optimization methods that are different from classical methods and give global solutions, are getting increasingly more attention. One of them is a genetic algorithm (GA) and is used in the problem of order reduction of linear system in this work. The main reason for using a GA here is its global solution finding property, without any need to give initial approximation to unknown parameters. GAs differ substantially from more traditional search and optimization methods. The first main difference is that a GA searches a population of points in parallel, rather than a single point, also a GA does not require any derivatives to be calculated, only the objective function and corresponding fitness levels influence the directions of search. The GA is a stochastic global search method that mimics natural biological evolution. GAs operate on a population of potential solutions applying the principle of survival of the fittest to produce (hopefully) better and better approximations to a solution. At each generation, a new set of approximations is created by the process of selecting individuals according to their level of fitness in the problem domain and breeding them together using operators borrowed from natural genetics. This process leads to the evaluation of population of individuals that are better suited to their environment than the individuals that they were created from, just as in natural adaptation. Details of the proposed method of linear discrete system order reduction using a GA are given in the following sections.

2. Problem formulation

If the transfer function of a stable high order linear discrete system $G_n(z)$ is

$$G_n(z) = \frac{c_{n-1}z^{n-1} + c_{n-2}z^{n-2} + \cdots\cdots + c_1 z + c_0}{z^n + d_{n-1}z^{n-1} + \cdots\cdots + d_1 z + d_0} \tag{1}$$

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