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Model order reduction using response-matching technique

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Abstract

A method for model order reduction is proposed using response-matching technique. The step and impulse inputs have been considered. All types of pole configurations in the original high-order and reduced low-order system are included in this paper like real, complex and repeated. The proposed method is comparable in quality with similar existing methods and is capable of generating a reduced-order model with a desired pole pattern.

Keywords: Order reduction; Impulse response; Step response

1. Introduction

While scanning the literature of order reduction it can be observed that papers can be divided into two groups: one dealing with only the order-reduction methodology and the other dedicated to application of these techniques.

As the work done in this research area is continuously in progress, it is useful to look into some works like that of Sinha et al. [1] and Sastry et al. [2]. In [1], the order-reduction methods are classified and discussed, whereas in [2] after a brief review of the order-reduction methods, a particular technique is successfully applied to the transient dynamic problems. It has been made clear in this paper that in a number of

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large-scale engineering problems, efficient handling of discretized computational model is possible using a reduced-order model derived from the finite element model of the original system. Further, it is also mentioned that out of the six basic approaches of order reduction like (1) parameter optimization, (2) aggregation, (3) singular perturbation, (4) model dominance, (5) component cost analysis and (6) internal balancing, the last three are found more convenient and meaningful in applications.

Apart from the ones mentioned above, a broad classification of order-reduction methods using response-matching techniques can be made in different ways like the one according to the type of input, i.e., sinusoidal signal or step and impulse input, and the other according to the fact whether the matching is defined 'a priori' or not. This classification can be used to understand the approach of response-matching techniques used for system order reduction.

Some related work of interest was done by Krajewski et al. [3] in 1990 using L_2-optimal pole retention technique. In this case, an expression for evaluating the minimum of the impulse response error norm for any choice of retained poles is derived in terms of the original system parameters, so that the truly dominant poles are determined in a simple manner. Numerator coefficients are obtained using an order recursive procedure. Although this method can be called a response-matching technique, it is computationally demanding and a simpler approach can be worked out.

In 1996, Hwang et al. [4] suggested a two-step iterative procedure for the optimal reduced-order modeling of linear time invariant SISO system. In this work, the performance index of optimal reduction is taken to be a quadratic function of the error between the time responses of the original and reduced models with a generalized input, but only the impulse and step inputs are considered. In this case, at each iteration cycle, the numerator dynamics is first determined by solving a set of linear equations, whereas the denominator polynomial is determined by a gradient search method. But the main feature of this method is that it searches the Routh stability parameters. Like the one discussed earlier [3], this method is also computationally complex and a simpler method is proposed in this paper.

The method developed by Howitt and Luus [5] is based on the fact that the reduced-order model (ROM) to be obtained will always be of second-order and all the coefficients of the numerator and denominator polynomials of the ROM transfer function are determined using the transient error minimization between the original high-order system (OHOS) and ROM. Further, in this approach the pole patterns chosen for the second order ROM are real distinct as well as a pair of imaginary poles only. In fact this was an improvement over the method proposed by Mukherjee et al. [6] because instead of retaining dominant poles, these are independently determined using the method of error minimization, whereas in [6] only the numerator polynomials of the ROM transfer function are determined using transient-error minimization.

The present attempt is towards the development of order-reduction methods where the input signals are step and impulse. In case of step input, matching is partially defined 'a priori' i.e., only the steady-state parts of the step input response