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Application of Grey Wolf Optimization in Order Reduction of Large Scale LTI Systems

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***Abstract*— A new nature inspired algorithm for order reduction of large scale linear time invariant (LTI) systems by Grey Wolf Optimization (GWO) has been presented. This technique is intended for both single-input single-output (SISO) and multi-input multi output (MIMO) systems. Here, application of the same in SISO LTI systems has been shown. GWO is a heuristic algorithm inspired by both the social hierarchy of wolves as well as their hunting behavior. Integral square error (ISE) in between the transient responses of original higher order and reduced order systems has been taken as an objective function, which is to be minimized. The step and frequency responses of both low and high order systems have also been compared along with the transient response's parameters. A comparative analysis of ISE with other existing methods in the literature has also been given in tabular and graphical forms to show the superiority of the algorithm.**

Keywords—Order Reduction, Grey Wolf Optimization, Linear Time-Invariant Systems, Integral Square Error.

I. INTRODUCTION

The mathematical model of a system is represented by higher order differential equations or difference equations. So, by using these difference equations, it is quite difficult to analyze the system. Thus for simplification of such systems, order of these equations must be reduced and this reduced system contains all the necessary properties of higher order system. Hence, model order reduction (MOR) is most widely used concept in different field of engineering for :

- Nonlinear inferential control.
- Efficient and reliable control system design.
- Computational speed.
- Satisfactory performance.
- Optimal and sub optimal control derived by simplified models, etc.

In recent years, model order reduction has been explored broadly by many researchers. Panda et al. [1-2] describes computational and evolutionary techniques for model order reduction. In most of the cases, it has been observed that low order system (LOS) is obtained by optimizing performance indices by evolutionary techniques and different approaches like; Factor Division, Improved Pole Clustering, Differential Evolution and Genetic Algorithm, etc [3-7].

Although having various order reduction techniques, no method provides satisfactory results so far, applicable for all type of systems. Therefore, to obtain approximate reduced order model from the higher order model is a benchmark in the field of control system due to various issues like; stability, reliability, large size of the system and good time/frequency response's matching.

Therefore, it is of large interest to explore the efficiency of new algorithms. In the present work, a new method for order reduction of LTI systems has been explored which is GWO based on hunting behavior of grey wolves. GWO has been used to minimize the ISE in between the transient responses of original HOS & LOS to get all the unknown parameters of LOS.

II. PROBLEM STATEMENT

Consider an n^{th} order SISO LTI HOS with the following transfer function :

$$G_n(s) = \frac{a_0 + a_1 s^2 + a_2 s^2 + \ldots\ldots\ldots + a_n s^{n-1}}{b_0 + b_1 s + b_2 s^2 + \ldots\ldots\ldots + b_n s^n} \qquad (1)$$

Let, the reduced r^{th} order LOS be given by following transfer function :

$$R_r(s) = \frac{\alpha_0 + \alpha_1 s + \alpha_2 s^2 + \ldots\ldots\ldots + \alpha_r s^{r-1}}{\beta_0 + \beta_1 s + \beta_2 s^2 + \ldots\ldots\ldots + \beta_r s^r} \qquad (2)$$

Now, the aim is to obtain all the unknown parameters of LOS in (2) by minimizing the objective function (which is ISE in the present work) using GWO subjected to unit step input. This ISE is given by [7] :

$$ISE = \int_0^\infty [y(t) - y_r(t)]^2 \, dt \qquad (3)$$

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