ABSTRACT

Stability is an important property to be possessed by every system. Since most of the systems are non-linear in nature, the analysis about the stability of a system can be acquired by employing suitable linearised models. The stability analysis of linear time invariant systems given in the form of characteristic equation can be performed using algebraic or graphical method. The characteristic equation is one kind of time invariant model. Even linear models may need further simplification to enable feasible analysis. Model reduction technique is used for this purpose. All model reduction techniques aim to provide a lower order model that will mimic the characteristics of the given higher order system. Also, the design of controllers and observers for higher order linear time invariant system involves large computational burden, which can be minimized with the help of suitable reduced order models.

The idea for the formulation of a second order model is due to the following two reasons: Firstly, they form an excellent basis for the analysis of the given system. Secondly, the characteristics of a second order model is identified by two parameters namely, the damping ratio and the undamped natural frequency of oscillation. By adjusting these two parameters, a suitable second order model for the given absolutely stable higher order system is evolved with the assured stability.

A summing procedure is proposed for the formulation of an initial second order model for a given absolutely stable higher order LTIS. The performance index of a second order model is recorded for the given unit step time response under the constraints of maintaining the characteristics of the original linear time invariant continuous system. The most useful performance index of lower order model is integral square error. The integral square error is used as a metrics for comparison. To minimize the integral square error the values of damping ratio ζ and undamped natural frequency ω_n is varied heuristically. This approach yields a second order model that mimics the original higher order system. For this, after a few trials of the observation made in the unit step responses, the choice for the changes in the values of ζ and ω_n are made. To overcome this limitation, genetic algorithm is employed to tune the values of ζ and ω_n of the initial second order model. It yields a second order model with a minimal integral square error. Unlike other algebraic and graphical model reduction techniques, the proposed GA approach iteratively evolves a second order model and the one with minimum integral square error imitates the characteristic of the given higher order system.

Thus the proposed methodology encompasses the following steps: (i) Applying the summing procedure for the formulation of an initial second order model. (ii) Applying genetic algorithm to improve the formulated second order model obtained in step (i) to mimic the given higher order system.

The proposed methodology for linear time invariant continuous system has been suitably extended for the discrete time system and multivariate systems. The effectiveness of the methodology has been established by comparing it with other model reduction techniques.

The formulated second order model has been utilized in the design of controllers or compensators to stabilize the given system satisfying certain time domain performance specifications. Genetic algorithm is applied to tune the parameters namely: proportional, integral and derivative involved in the design of controllers. For reducing the computational burden, the controller is designed for the formulated second order model of the given higher order system and when it is found to make the second order model stable within the given performance specifications, it is cascaded with the original higher order system to validate the actual stabilization process.

The thesis work also presents a genetic algorithm based methodology to design a state space controller and observer based on the characteristics of a second order model of a given higher order system. The controller and observer is initially designed for a second order model satisfying the given time domain performance specifications and its gain matrix is computed. The gain matrix of the higher order system is derived based on the gain matrix of the second order model.

The objective of this research is to develop computer-aided algorithms for model reduction and applying it for the design of controllers and observers in engineering applications. The numerical examples presented in this research work show that the proposed methodologies are suitable for the analysis and design of controllers and observers of absolutely stable linear time invariant systems.