Metaheuristic Approaches to Model Order Reduction: Challenges And Future Prospects

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The mathematical modelling of physical systems leads to a comprehensive description of the models. But difficulty arises while analysing the system or developing its control scheme. Thus, it is required to constitute a diminished model which preserves the inherent features of the parent system. Parallel to the classical techniques, researchers have also started exploring in recent times the problem of model reduction with the help of nature inspired or metaheuristic algorithms. But there are certain perennial problems of order reduction using metaheuristic approaches for which it is still not a popular choice. Most of the metaheuristic techniques are stochastic in nature and give rise to different solutions on each independent run. Hence, multiple runs are required to test the accuracy of the results. Some statistical measures like best, worst, average and standard deviation of the error function need to be calculated. Even some non-parametric statistical tests may also be conducted to validate the results with reference to the other metaheuristic techniques. Kruskal Wallis test, Wilcoxon's signed rank and rank-sum tests etc. are usually some of the commonly used tests available in the literature that can be employed to test the significance of the results. Moreover, the dc gain of the original and the reduced systems must match. This can be made possible by applying suitable equality constraint. In addition to this, reduced system must preserve the stability of the parent model. This can also be satisfied with some constraint to have the poles of the reduced-order model on the left half of the s-plane. Further, the reduced system should not have a zero on the right half of s-plane. This can be avoided by an appropriate inequality constraint. Even constraints can be set for matching the important time and frequency domain measures. So, it is thereby proved that the model reduction techniques using metaheuristic-based methods will require to solve constrained optimization problem. There are moreover choices like population size, maximum number of iterations and search bounds of the model parameters to be estimated that are arbitrary. So far decision is taken either on the prior experience or by means of trial and error. A higher choice of population size, say for example 50 or 100 will stabilize the result on each run. The number of function evaluations, obtained by the product of the population size and the number of iterations can be checked out from the number of decision variables considered to be estimated. Some researchers also estimate the parameters of the denominator polynomial with the aid of classical based approaches. Stability equation method and moment matching technique are widely reported in the literature. This also reduces the number of decision variables and constraints in the optimization problem. Normally a response matching technique is adopted to identify the model parameters of the reduced system. As per literature records, majority of the response matching took place with step input and some with impulse input. Few authors have also considered the unbiased pseudo random binary sequence (PRBS) as the input signal to match the responses of the original and reduced models to obtain the unknown variables. Comparing the time and frequency domain parameters of the reduced model with that of the parent system is also a good practice. Some authors also provide graphically the step and Bode responses of the parent and reduced models to show the closeness of the model. There is also a practice to measure the different popular error indices in systems and control and show comparison with the existing methods. So far only the single objective optimization methods are used to obtain the model parameters. A good multi-objective procedure can be taken up to solve efficiently the model reduction problem. Hybrid computing techniques has been utilized recently to develop reduced-order models. Formulation of new techniques can be taken up for the investigation. So metaheuristic approaches can give a healthy competition to the age old classical methods in solving model reduction problems.

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