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A NEW MIXED METHOD FOR REDUCTION OF MIMO SYSTEM USING ARTIFICIAL BEE COLONY OPTIMIZATION ALOGIRITHM AND POLY NOMIAL METHOD

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ABSTRACT: In this paper, a new mixed method is used for MIMO system to reducing the higher order to lower order system. The denominator polynomial is derived by an Optimization algorithm based on the intelligent foraging behaviour of honey bee swarm, called Artificial Bee Colony(ABC) and the numerator coefficients are derived by the polynomial method. The reduction procedure is simple, efficient and computer oriented. The proposed method guarantees stability of the reduced order model if the original higher order system is stable. The validity of algorithm is illustrated with the help of two numerical examples considered from the literature and the results are compared with other recently published reduction techniques to show its superiority.

Keywords: Model Order Reduction, Artificial Bee Colony, Polynomial method, Integral Square Error (ISE), Stability.

INTRODUCTION

The modelling of complex dynamic systems is one of the most important subjects in Engineering and Science. The mathematical procedure of system modelling often leads to higher order differential equations which are too complicated to use either for analysis or controller synthesis. So approximation procedures based on physical considerations (or) mathematical approaches are used to achieve simpler models for the original one. These reduction techniques are well-established part of the control system designer's toolkit. At the forefront of these techniques have been those that deal with the linearized system models in both the time and frequency domains[1-4]. The most desirable properties of any order reduction techniques is that preserving stability of the original model in the reduced model and matching of time responses. In spite of several methods available, no single approach always gives the best results for all systems.

Many approaches have been proposed for reducing MIMO systems from higher order to lower order system. Shamash [13] proposed a method of reduction using pade approximation. The disadvantage of this method is reduced order model may be unstable even though the original high order system is stable. Anurg vijay Agarwal and Ankit Mittal Is proposed a method for MIMO system is Eigen spectrum analysis and CFE form, which is also some disadvantage.

Recently, The Artificial Bee Colony Algorithm (ABC) appeared as promising evolutionary technique for handling the optimization problems, which is based on the intelligent foraging behaviour of honey bee swarm, proposed by Karaboga in 2005[7-8]. This swarm algorithm is very simple and flexible when compared to the other existing swarm based algorithms. It can be used for solving uni-model and multi-model numerical optimization problems. This algorithm uses only common control parameters such as colony size and maximum cycle number. It is a population based search procedure and can be modified using the artificial bees with time and the aim of the bees is to discover the places of food sources with high nectar amount and finally choose source with the highest nectar amount among the other resources.

In the present paper to overcome above problem a mixed method is proposed. The denominator polynomials of the reduced order model are determined by using ABC techniques and the numerator coefficients are obtained by polynomial technique. The proposed method is compared with the other well known order redactor techniques available in the literature.

DESCRIPTION OF PROBLEM

Let the transfer function matrix of the high order 'n' having 'p' inputs and 'm' outputs be

$$G(s) = \frac{1}{D(s)} \begin{bmatrix} a_{11}(s) & \cdots & a_{1p}(s) \\ \vdots & \ddots & \vdots \\ a_{m1}(s) & \cdots & a_{mp}(s) \end{bmatrix} \quad (1)$$

Or, $[G(S) = g_{ij}(s)]$ i=1,2,……m, j=1,2,….p is a m x p matrix. The general form of $[g_{ij}(s)]$ of $[G(s)]$ is taken as

$$g_{ij}(s) = \frac{a_{ij}(s)}{D(s)} = \frac{a_0 + a_1 s + a_2 s^2 + \cdots \ldots \ldots . a_{m-1} s^{n-1}}{b_0 + b_1 s + b_2 s^2 + \cdots \ldots \ldots . b_n s^n}$$

Let the transfer function of matrix of the lower order 'k' having same number of inputs and outputs to be synthesized as

$$R_k(s) = \frac{1}{D_k(s)} \begin{bmatrix} b_{11}(s) & \cdots & b_{1p}(s) \\ \vdots & \ddots & \vdots \\ b_{m1}(s) & \cdots & b_{mp}(s) \end{bmatrix}$$

(2)

Or $[R_K(S) = r_{ij}(s)]$, i=1, 2…m and j=1, 2…..p is an m x p transfer matrix. The general form of $[r_{ij}(s)]$ of $[R_k(s)]$ can be written as

$$r_{ij}(s) = (b_1 ij\ (s))/(D_1 k\ (s)) = \frac{d_0 + d_1 s + d_2 s^2 + \cdots \ldots \ldots . d_{k-1} s^{k-1}}{e_0 + e_1 s + e_2 s^2 + \cdots \ldots \ldots . e_k s^k}$$

A). Determination of denominator by ABC algorithm

ABC is a population based optimization algorithm based on intelligent behaviour of honey bee swarm [7]. In the ABC algorithm, the foraging bees are classified into three categories; Employed bees, Onlookers and Scout bees. A bee waiting on the hive for making decision to choose a food source is called an Onlooker and a bee going to the food source visited by it previously is named an Employed bee. A bee carrying out random search is called a Scout. The employed bees exploit the food source and they carry the information about the food source back to the hive and share information with onlookers. Onlooker bees are waiting in the hive at dance floor for the information to be shared by the employed bees about their discovered food sources and scouts bees will always be searching for new food sources near the hive. Employed bees share information about food sources by dancing in the designated dance area inside the hive. The nature of dance is proportional to the nectar content of food source just exploited by the dancing bee. Onlooker bees watch the dance and choose a food source according to the probability proportional to the quality of that food source. Therefore, good food sources attract more onlooker bees compared to bad ones. Whenever a food source is exploited fully, all the employed bees associated with it abandon the food source and become scout. Scout bees can be visualized as performing the job of exploration, where as employed and onlooker bees can be visualized as performing the job of exploitation.

In the ABC algorithm, each food source is a possible solution for the problem under consideration and the nectar amount of a food source represents the quality of the solution which further represents the fitness value. The number of food sources is same as the number of employed bees and there is exactly one employed bee for every food source. At the first step, the ABC generates a randomly distributed initial population *P* (*C=0*) of SN solutions (food sources position), where SN denotes the size of population. Each solution (food sources) $X_i\ (i = 1, 2 \ldots SN)$ is a *D*-dimension vector. Here *D* is number of optimization parameters. After initialization, the population of the position (solution) is subjected to repeated cycles, $C = 1, 2 \ldots C_{\max}$ of the search process of the employed bees, onlookers and scouts. The production of new food source position is also based on comparison process of food source's position. However, in the model, the artificial bees do not use any information in comparison. They randomly select a food source position and produce a modification on the existing, in their memory as described in Eq.(5) provided that the nectar amount of the new source is higher than that of the previous one of the bee memorizes the new position and forgets the old position. Otherwise she keeps the position of the previous one. An onlooker's bees evaluate the nectar information taken from all employed bees and choose a food source depending on the probability value associated with that food source P_i, calculated by the following equation:

$$P_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n} \quad \ldots (4)$$

Where fit_i is the fitness value of the solution '*i*' evaluated by its employed bee, which is proportional to the nectar amount of food source in the position $'i'$ and SN. In this way, the employed bees exchange their information with the onlookers. In order to produce a new food position from the old one, the ABC uses following expression (5):

$$v_{ij} = x_{ij} + \emptyset_{ij}(x_{ij} - x_{kl}) \quad \ldots (5)$$

Where $k \in (1, 2, \ldots BN)$ and $l \in (1, 2 \ldots D)$ are randomly chosen indexes. Although 'k' is determined randomly, it has to be different from $'i'$. $\emptyset_{ij}$ is a random number between [-1, 1]. It controls the production of neighbour food source position around $x_{i,j}$ and the modification represents the comparison of the neighbour food positions visualized by the bee. Equation (5) shows that as the difference between the parameters of the $x_{i,j}$ and $x_{k,j}$ decreases, the perturbation on the position $x_{i,j}$ decreases too. Thus, as the search approaches to the optimum solution in the search space, the step length is adaptively reduced. If its new fitness value is better than the best fitness value achieved so far then the bee moves to this new food source abandoning the old one, otherwise it remains in its old food source. When all employed bees have finished this process, they share the fitness information with the onlookers, each of which selects a food source according to probability given in Eq. (4). With this scheme, good food sources will get more onlookers than the bad ones. Each bee will search for better food source around neighbourhood path for a certain number of cycles (limit), and if the fitness value will not improve then that bee becomes scout bee.

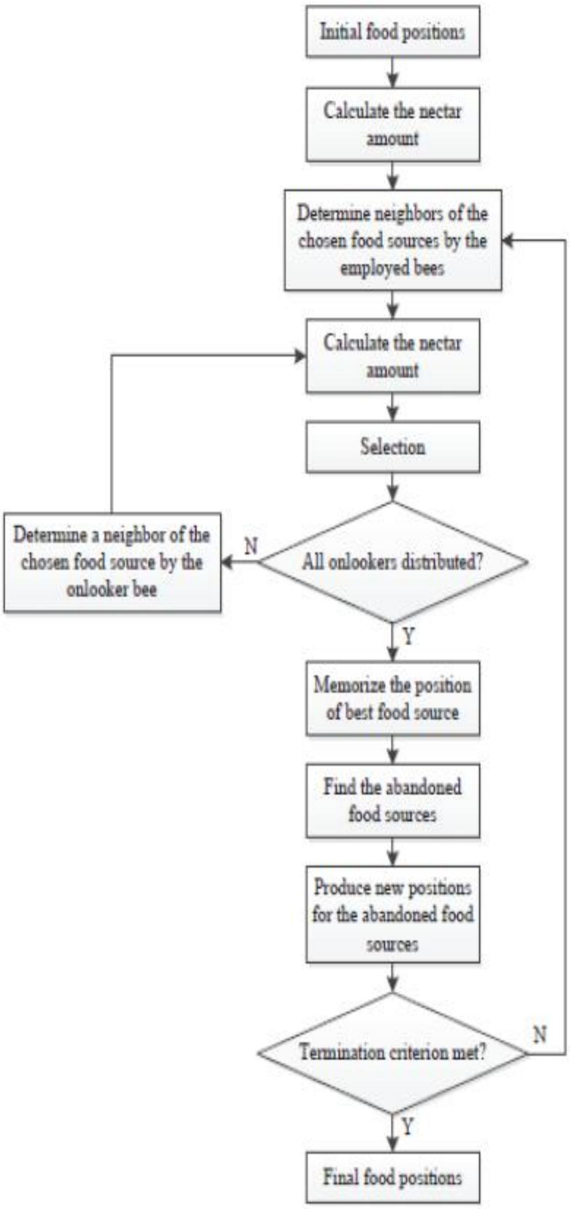

Fig.1. Flow chart of ABC algorithm

B).<u>Determination of numerator by polynomial method</u>

The numerator polynomial is obtained by equating the original system with reduced order system .

$$\frac{a_0 + a_1 s + a_2 s^2 + \cdots \dots \dots a_{n-1} s^{n-1}}{b_0 + b_1 s + b_2 s^2 + \cdots \dots \dots b_n s^n} = \frac{d_0 + d_1 s + d_2 s^2 + \cdots \dots \dots d_{k-1} s^{k-1}}{e_0 + e_1 s + e_2 s^2 + \cdots \dots \dots e_k s^k} \quad (7)$$

Equate the same power's of 'S' on both sides, we get

$$a_0 e_0 = b_0 d_o \quad (8)$$

$$a_0 e_1 + a_1 e_0 = b_0 d_1 + b_1 d_0 \quad (9)$$

$$a_0 e_2 + a_1 e_1 + a_2 e_0 = b_0 d_2 + b_1 d_1 B_2 d_0 \quad (10)$$

$$a_{m-1} e_k = b_n d_{k-1} \quad (11)$$

From the above equations we can get the values of $d_0, d_1 \dots d_q$.

NUMERICAL EXAMPLES

Numerical example is chosen from the literature to show the flexibility and effectiveness of the proposed reduction algorithm than other existing methods, and the response of the original and reduced models are compared.

Example1: Let us consider the system transfer function.

$$G(s) = \frac{\begin{bmatrix} g_{11}(s) & g_{12}(s) \\ g_{21}(s) & g_{22}(s) \end{bmatrix}}{D_4(s)} \quad (12)$$

Where

$g_{11}(s) = 2s^5 + 70s^4 + 762s^3 + 3616s^2 + 7820s + 6000$

$g_{12}(s) = s^5 + 38s^4 + 459s^3 + 2182s^2 + 4160s + 2400$

$g_{21}(s) = s^5 + 30s^4 + 331s^3 + 1650s^2 + 3700s + 3000$

$g_{22}(s) = s^5 + 42s^4 + 601s^3 + 3660s^2 + 9100s + 6000$

$D_4(s) = s^6 + 41s^5 + 571s^4 + 3491s^3 + 10060s^2 + 13100s + 6000$

The obtained denominator from ABC algorithm is

Swarm size = 50 (Number of reduced order models)

Unknown coefficients = 2

Number of iterations = 1000

The reduced order denominator is

$$D_2(s) = 17.1455 + 19.42475s + s^2$$

For finding the numerator values, use the polynomial technique. Equate original transfer function and reduced order transfer function with obtained denominator..

$$\frac{2s^5 + 70s^4 + 762s^3 + 3610s^2 + 7000s + 6000}{s^6 + 41s^5 + 571s^4 + 3491s^3 + 10060s^2 + 13100s + 6000} = \frac{d_0 + d_1 s}{17.1455 + 19.42475s + s^2}$$

On cross multiplying the above equations and comparing the same power of 's' on the both sides, we get numerator value and multiply the numerator with 'k.'

Therefore, the numerator by polynomial method

$$N_2(s) = 4.3808s+17.1453 \quad (14)$$

The proposed second order reduced model using mixed method for transfer function1 is obtained follows

$$R_{2a}(s) = \frac{4.3808s + 17.1453}{17.1455 + 19.42475s + s^2}$$

Similarly The proposed second order reduced model using mixed method for remaining transfer functions are obtained follows

$$R_{2b}(s) = \frac{9.324 + 4.662s}{17.1455 + 19.42475s + s^2} \quad (16)$$

$$R_{2c}(s) = \frac{9.747 + 6.0316s}{17.1455 + 19.42475s + s^2} \quad (17)$$

$$R_{2d}(s) = \frac{23.329 + 4.665s}{17.1455 + 19.42475s + s^2} \quad (18)$$

The second order reduced models using mihilov and continued fraction method are shown below.

$$R_{2a1}(s) = \frac{8.4707 + 6.0429s}{8.4707 + 13.666s + s^2}$$

$$R_{2b1}(s) = \frac{3.3883 + 3.9491s}{8.4707 + 13.666s + s^2}$$

$$R_{2c1}(s) = \frac{4.2354 + 2.8095s}{8.4707 + 13.666s + s^2}$$

$$R_{2d1}(s) = \frac{8.4707 + 8.0195s}{8.4707 + 13.666s + s^2}$$

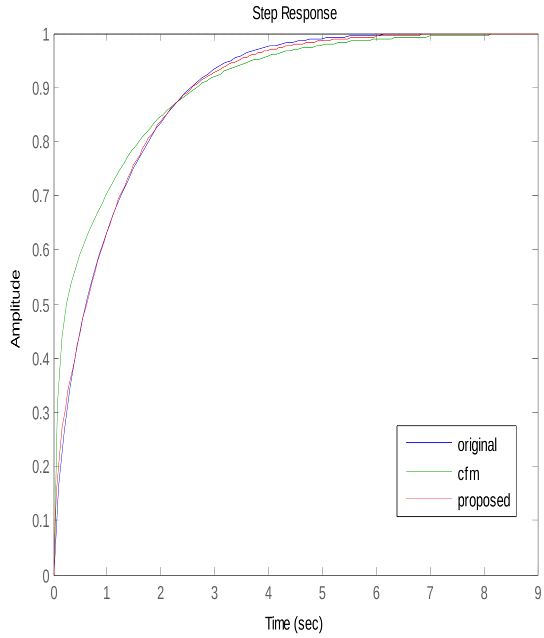

Fig1: Step responses of original and reduced order model for 1^{st} output

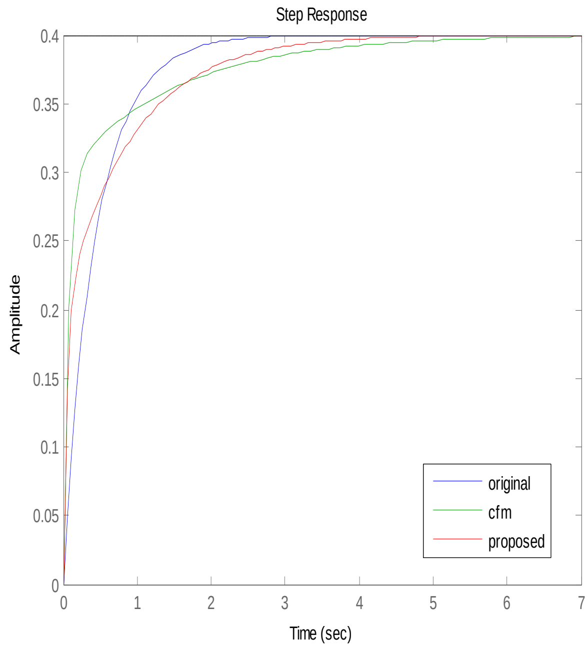

Fig2: Step responses of original and reduced order model for 2^{nd} output

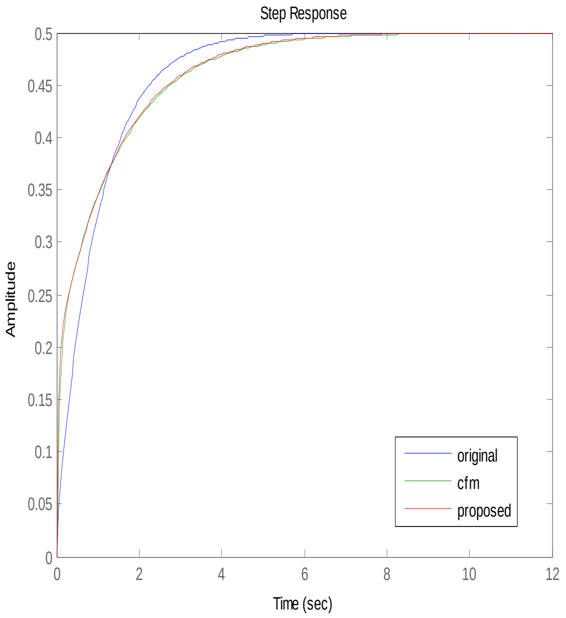

Fig3: Step responses of original and reduced order model for 3^{rd} output

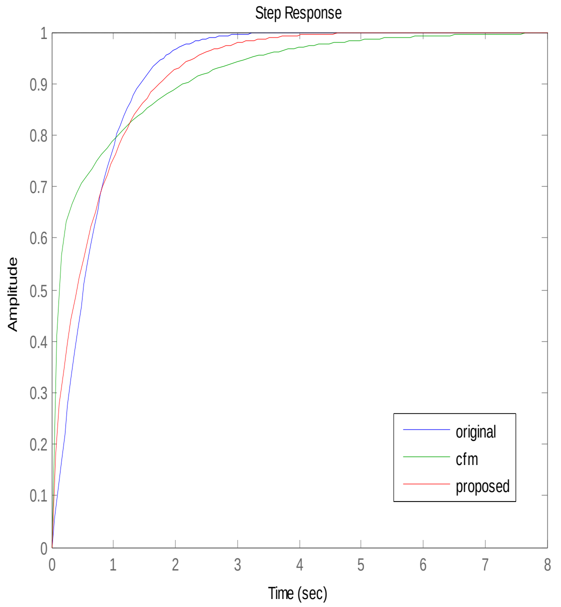

Fig4: Step responses of original and reduced order model for 4th output

CONCLUSION

In this paper, a new mixed method is used for reducing MIMO system from high order system into a lower order system which has been proposed. In this denominator polynomial is obtained by ABC algorithm technique and numerator polynomial is obtained by polynomial method. The method has been tested using numerical examples. The results of this method are compared with the other existing methods available in literature shown in figures. From these comparisons, it is concluded that the proposed method is simple; computer oriented and achieves better approximations than the other existing methods. ABC method is based on the minimization of the integral squared error (ISE) between the transient responses of original higher order model and the reduced order model pertaining to a unit step input. This method guarantees stability of the reduced model if the original high order system is stable and which exactly matches the steady state value of the original system.

REFERENCES

[1] R. Genesio and M. Milanese, “A note on the derivation and use of reduced order models”, *IEEE Trans. Automat.Control*, Vol. AC-21,No. 1, pp. 118-122, February 1976.

[2] M. Jamshidi, *Large Scale Systems Modelling and Control Series*, NewYork, Amsterdam, Oxford, North Holland,Vol. 9, 1983.

[3] G.Parmar, R.Prasad and S.Mukherjee, “Order reduction of linear dynamic systems using stability equation method and GA”, *World Academy of science engg. and tech.* Vol-26 ,2007.

[4] C.B. Vishwakarma , R. Prasad, “Research Article MIMO system reduction using Modified Pole clustering and GA ,*Hindawi publishing corp, Modelling and simulation in engg*,vol-2009, Article id-540895, 5pages.

[5] G.Parmar, R.Prasad, S.Mukherjee , *International Journal of Computation and Mathematical Sciences* 1;2007.

[6] G.D. Howitt, and R. Luus, “Model reduction by minimization of integral square error performance indices”, *Journal of Franklin Inst.*, Vol. 327, pp. 343-357, 1990.

[7] D.Karaboga, “An idea based on Honey Bee Swarm for Numerical Optimization, Technical Report – TR06,Erciyes university, Computer Engineering Department, OCT-2005.

[8] D.Karaboga, B.Basturk, “A powerful and efficient algorithm for numerical function optimization: Artificial Bee Colony (ABC) algorithm, *Journal of Global Optimization*, Vol: 39, Issue 3, pp: 459-471, Springer Netherlands, 2007.

[9] V.Singh, D. Chandra and H. Kar, “Improved Routh Pade Approximants: A computer aided approach”, *IEEE Trans. Automat. Control*, Vol.49, No.2, pp292-296, February-2004.

[10]T.N.Lucas, “Further Discussion on Impulse Energy Approximation”, *IEEE Trans. Automat .Control*, Vol.AC-32, No. 2 , pp. 189-190,FEB-1987.

[11] G.Parmar, S.Mukherjee, R.Prasad, *International Journal of Computer, Information and Systems Science and Engineering* 1;2-2007.

[12] Y S Kumar, P K Ghosh, S Mukherjee, “Model Order Reduction using Bio-inspired PSO and BFO soft computing for Comparitive Study”, *Int .J. of information and communications*,Vol.1,No.1, June-2011.

[13 Y.Shamash. "Multivariable System Reduction via Modal Methods and Pade Approximation" IEEE Trans.Aut.Cont.AC-20: pp 815-817, 1975.

[14] S.Mukherjee, Satakshi and R.C.Mittal, *Journal of Franklin Inst.*, Vol. 342 , pp.503-519, 2005.

[15] J. Pal, *Electronic Letters*, Vol. 15, No.8,pp.225-226, April 1979.

[16] T.C. Chen, C.Y. Chang, and K.W. Han , *Int. J. Control*, Vol. 32, No. 1, pp. 81-94, 1980.

[17] M. G. Safonov, R. Y. Chiang and D. J. Limebeer, "Optimal Hankel model reduction for nonminimal systems", *IEEE Trans. Automat Control*, Vol. 35, No.4, pp 496-502, April 1990.

[18] T.Manigandan *et al*., *Academic Open Internat Journal;* Vol- 15, 2005.

[19] C.S.Hsien, C.Hwang, *IEE Proceedings*, Vol.136, Pt.d, No.4, July-1989.

[20] R.Prasad, S.P.Sharma, A.K.Mittal, *IE(I)Journal.El*, Vol-84, Jun-2003.

[21] Y.Shamash , *Int.J.Control*, Vol-21, pp475-484, 1975.