International Journal of Engineering
Journal Homepage: www.ije.ir

RESEARCH NOTE

Design of IIR Digital Filter using Modified Chaotic Orthogonal Imperialist Competitive Algorithm

M. Sharifi[a], H. Mojallali*[b]

[a] *Department of Electrical, Computer and Biomedical Engineering, Islamic Azad University, Qazvin Branch, Qazvin, Iran*
[b] *Electrical Engineering Department, Faculty of Engineering, University of Guilan, Rasht, Iran*

P A P E R I N F O

Paper history:
Received 02 June 2013
Received in revised form 04 October 2013
Accepted 12 December 2013

Keywords:
IIR Digital Filter
Imperialist Competitive Algorithm
Optimization
Evolutionary Algorithm

A B S T R A C T

There are two types of digital filters including Infinite Impulse Response (IIR) and Finite Impulse Response (FIR). IIR filters attract more attention as they can decrease the filter order significantly compared to FIR filters. Owing to multi-modal error surface, simple powerful optimization techniques should be utilized in designing IIR digital filters to avoid local minimum. Imperialist competitive algorithm is an evolutionary algorithm used in solving optimization problems in recent years. It can find global optimum response in a nonlinear searching space. In this paper, performance of chaotic orthogonal imperialist competitive algorithm has been improved through some variations in it. Then, this modified algorithm has been applied in designing IIR digital filters and their performance has been compared to some evolutionary algorithms.

doi:*10.5829/idosi.ije.2014.27.07a.04*

1. INTRODUCTION

Digital filters apply mathematic functions on discrete signals and change some of their properties. For example, they remove noise from them or allow a particular frequency range of a signal to pass and omit the others. These filters have two typesincluding Infinite Impulse Response (IIR) and Finite Impulse Response (FIR). Compared to FIR filters, IIRs require less delay, adder and multiplier elements. In other words, they need fewer coefficients and attract more attention as they can reduce the filter order significantly compared to FIR filters. If there is not sufficient data about desired system or the characteristics are not fulfilled by time invariant filters, adaptive filters would be utilized [1, 2]. Adaptive filters adjust their transfer function according to the input and adapt themselves with it. These filters are applied to channel equalization [3], active noise control [4] and echo cancelation [5]. System identification is one of thebasic applications of adaptive filters and this paper uses it in designing IIR digital filters.Although an IIR filter can provide a much better performance than a FIR filter having the same number of coefficients, some problems arise in the design of IIR digital filters. One problem is the possibility of filter instability duringadaptation process. This problem can be easily handled by limiting the parameter space. However, the major problem in IIR digital filter design is a multi-modal error surface. Hence, the general optimization techniques are required to avoid local minimum.

In recent years, different researches have been conducted to introduce general, flexible and powerful designing methods based on evolutionary optimization algorithms for IIR digital filters. These methods can find the global optimum response in a nonlinear searching space and scape from local minimum. Some utilized evolutionary algorithms include genetic algorithm [6], particle swarm optimization algorithm [7] and harmony search algorithm [8].The imperialist

*Corresponding Author's Email: mojallali@guilan.ac.ir (H. Mojallali)

Please cite this article as: M. Sharifi, H. Mojallali, Design of IIR Digital Filter using Modified Chaotic Orthogonal Imperialist Competitive Algorithm. International Journal of Engineering (IJE) Transactions A: Basics, Vol. 27, No. 7, (2014): 1033-1040

competitive algorithm (ICA) is one of the evolutionary algorithms. It was introduced by Caro Lucas and Atashpaz [9].

This novel optimization method is based on a socio-politically motivated strategy. The ICA is a multi-agent algorithm in which each agent is a country and can be either a colony or an imperialist. These countries form some empires in the search space. Movement of the colonies toward their related imperialist and imperialistic competition among the empires forms the basis of the ICA. During these movements, the powerful imperialists are reinforced and the weak ones are weakened and gradually collapsed, directing the algorithm towards optimum points. Imperialistic competition is the main part of the ICA and hopefully causes the colonies to converge the global minimum of the cost function [10].

In addition, appropriate modification in some of the algorithms stages may facilitate their optimization. Recently, the idea of using chaotic systems instead of random processes has been noticed in several fields. One of these fields is optimization theory. In random-based optimization algorithms, the role of randomness can be played by a chaotic dynamics. Experimental studies assert that the benefits of using chaotic signals instead of random signals are often evident, although it is not mathematically proved yet.

For example in evolutionary algorithms (EA's), chaotic sequences increase the value of some measured algorithm performance indexes with respect to random sequences. Tacking properties of chaos like ergodicity, some new searching algorithms called chaos optimization algorithms are presented in literature. These algorithms can be more easily escaped from local minima than other stochastic optimization algorithms. Stochastic optimization algorithm often escape from local minima by accepting some bad solutions according to a certain probability but chaos optimization algorithms searches on the regularity of chaotic motion to escape from local minima [11].The main purpose of the present paper is to show that chaotic orthogonal imperialist competitive algorithm would be changed and so make it conditioned; adding this condition results in better response space searching and improves the algorithm performance.

IIR digital filter designing problem is described in section 2 of the paper. Imperialist competitive algorithm and its orthogonal version are introduced in section 3. The next section presents the chaotic orthogonal imperialist competitive algorithm and modified chaotic orthogonal imperialist competitive algorithm. Section 5 investigates applying this modified algorithm in designing IIR digital filter. Then, the obtained results are compared with the results obtained from genetic, particle swarm optimization, cuckoo optimization algorithms [12], imperialistcompetition and orthogonal imperialist competition by this modified algorithm.

2. STATEMENT OF THE PROBLEM

The relation between input, output and the transfer function of IIR digital filter is as follows:

$$y(n) = \sum_{k=0}^{U} b_k\, x(n-k) - \sum_{k=0}^{V} a_k\, y(n-k) \quad (1)$$

$$H(z) = \frac{\sum_{k=0}^{U} b_k Z^{-k}}{1+\sum_{k=1}^{V} a_k Z^{-k}} \quad (2)$$

a_k and b_k are filter coefficients, x(n) and y(n) are input and output, respectively. Since the desired criterion system is unknown, IIR digital filter design is defined as system identification problem in Figure 1 [13–18]. In fact, IIR digital filter designing problem could be as minimization of a cost function where it is defined as mean squared error according to Equation (3). When this means reaches its minimum value, optimum weights are obtained for the filter.

$$J(w) = \frac{1}{N}\sum_{k=1}^{N}\left[d(k)-y(k)\right]^2 \quad (3)$$

$w=[a_0 a_1 \ldots a_L b_1 b_2 \ldots b_M]^T$is the filter coefficients vector and d(k) and y(k) are desired filter response and designed filter response, respectively and N is the length of filter input signal.

3. IMPERIALIST COMPETITIVE ALGORITHM

3. 1. Standard Imperialist Competitive Algorithm

Imperialist competitive algorithm presents an algorithm to solve mathematic problems of optimization by mathematic modeling of political and social evolution process and has shown its good performance. This algorithm forms an initial set of random responses as other evolutionary algorithms. The initial responses are known as a set of countries and they are formed according to Equation (4).

$$x = x_{min} + (x_{max} - x_{min}) \times \text{rand}(1, n_{var}) \quad (4)$$

n_{var} is the number of variables and x_{min} and x_{max} are low and high limits of the variables.

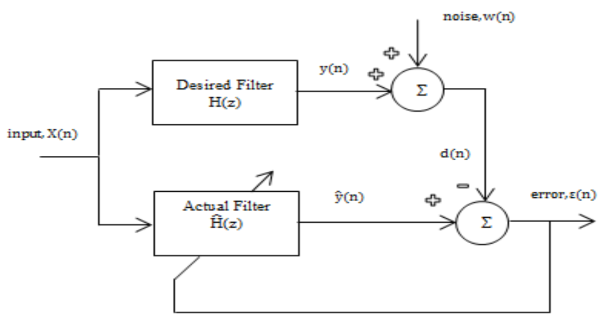

Figure 1. Block diagram of system identification process using adaptive IIR filter

Some countries at better condition are determined as imperialist and some colonies are allocated to each imperialist based on the probability of each one. The probabilities are determined through Equation (5).

$$p_i \propto e^{-\alpha c_i} \quad (5)$$

α is the parameter of selection pressure. It is selected in a way that sum of the probabilities of the population better half is about 0.8; c_i is the value of cost function of i^{th} imperialist.

In assimilation stage, countries move towards their imperialist. If the current position of the colony is x and the imperialist's position is t, the colony moves towards the imperialist in the direction of distance vector between colony and imperialist. The movement is according to Equation (6). Figure 2 indicates how the colony moves towards the imperialist.

$$x' = x + \beta \times \{r\} \otimes (t - x) \quad (6)$$

where β is greater than 1 and close to 2 and β > 2 values cause instability, r is random vector equal to the problem dimensions and is used to cause deviation on the way of movement.

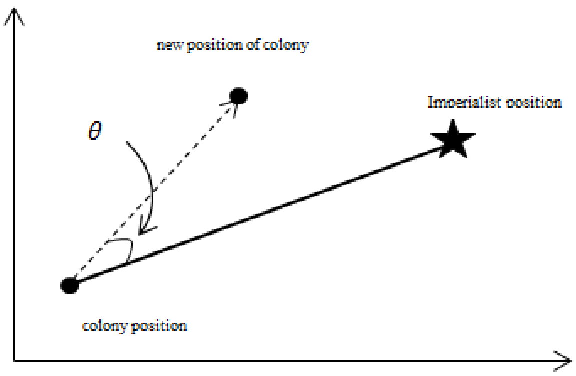

Figure 2. Movement of colony to its new location in the standard ICA.

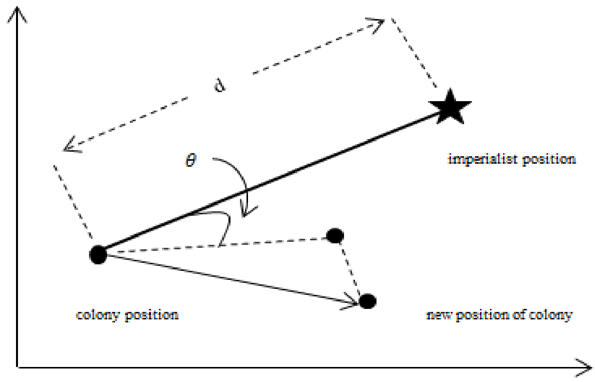

Figure 3. Movement of colony to its new location in the orthogonal ICA.

In imperialist competitive algorithm, revolution is modeled by random movement of a colony and getting placed at a new random position. From algorithm viewpoint, revolution rescues the totality of evolutionary movement from local minimum which improves the country situation in some cases. According to Equation (7), random variations could be made in the countries' conditions to cause revolution through normal distribution.

$$x' \sim N(x, \sigma^2) \sim x + \sigma N(0,1) \quad (7)$$

σis the step length and its value is often considered to be equal to ŋ ($x_{max} - x_{min}$) where ŋ is almost equal to 0.1. After assimilation and revolution, some colonies may reach a better position than the imperialist. In this case, the imperialist country is replaced by the colony. Then, emperors compete. An emperor's power is defined as the imperialist power plus a percentage of the colonies' total power. Value of the objective function of each emperor is defined as Equation (8):

$$\text{Total cost} = f(imp) + \zeta \times \text{mean}(f(col)) \quad (8)$$

ζ determines more or less imperialist or colony role in the emperor objective function. Its value is less than one. Weak imperialists lose their colonies and the more powerful ones add these colonies to their colonies, gradually. When an imperialist loses all its colonies, it becomes the colony of one of the imperialists. These stages would be repeated frequently until stopping criteria are satisfied.

3. 2. Orthogonal Imperialist Competitive Algorithm (OICA) Orthogonal imperialist competitive algorithm (OICA) has been presented recently [19]. This algorithm has emerged through modifying the movement of colonies towards emperors in the assimilation stage of imperialist competitive algorithm. In this version, after the colony moves towards the imperialist according to Equation (6) in assimilation stage and reaching the new position, it moves in a way perpendicular to the distance vector between colony and imperialist where the movement facilitates searching the response space. Figure 3 shows the direction of this movement. New position of the colony is obtained in assimilation stage of the orthogonal imperialist competitive algorithm version according to Equation (9). Other stages are similar to the standard imperialist competitive algorithm and no change happens in them.

$$x = x + \beta \times \{rand\} \otimes \{t - x\} + U(-1, +1) \times \tan(\theta) \times d \times \{v_2\} \quad (9)$$

v_2 is perpendicular to distance vector between imperialist and colony and d is the distance size between imperialist and colony positions.

4. MODIFIED CHAOTIC IMPERIALIST COMPETITIVE ALGORITHM (COICA)

4. 1. Chaos Theory and Chaotic Map Chaos theory is a field of mathematics and physics related to the systems which their dynamic shows a very sensitive behavior against change in the initial values and future behaviors are not predictable anymore. This behavior is called butterfly effect. Chaotic systems are utilized widely in different grounds like pattern identification, optimization theory, etc.

One-dimensional noninvertible maps are the simplest systems with capability of generating chaotic motion. Logistic map is a known chaotic map presented by Robert May [20] and according to Equation (10):

$$y_{k+1} = c.\, y_k\,(1 - y_k) 0 < c \le 4, \quad y_k \in (0, 1) \tag{10}$$

c is control parameter and guarantees chaotic movement, where at $y_k = \frac{x_k + 1}{2}$ and c = 4, Equation (10) becomes $x_{k+1} = 1 - 2(x_k)^2$. Having hypothesized 'r' as control parameter, logistic map improves as Equation (11) [21].

$$x_{k+1} = 1 - r\,(x_k)^2 \quad 0 < r \le 2\,, \quad x_k \in (-1\,,\,1) \tag{11}$$

Chaotic map of the current paper is a one-dimension map and Equations (12) and (13) show the relationship between variable value in the present and next iteration according to the range of initial values.

$$x_{k+1} = 4\, x_k (1 - x_k) \qquad 0 < x_k < 1$$

$$x_0 \notin \{0\,,\, 0.25,\, 0.75\,,\, 1\} \tag{12}$$

$$x_{k+1} = 1 - 2x_k^2 -1 < x_k < 1 \tag{13}$$

4. 2. Chaotic Orthogonal Imperialist Competitive Algorithm (COICA) Premature convergence in local minimum is some deficiencies of evolutionary algorithms. Chaotic sequence produced by chaotic maps could be used instead of random numbers in optimization algorithms. Owing to non-repetitiousness of chaotic variables, chaotic optimization algorithm may search the response space better than random optimization algorithm. The basic process of chaos optimization algorithm generally includes two major steps. Firstly, define a chaotic sequences generator based on the Logistic map. Generate a sequence of chaotic points and map it to a sequence of design points in the original design space. Then, calculate the objective functions with respect to the generated design points, and choose the point with the minimum objective function as the current optimum. Secondly, the current optimum is assumed to be close to the global optimum after certain iterations, and it is viewed as the center with a little chaotic perturbation, and the global optimum is obtained through fine search. Repeat the above two steps until some specified convergence criterion is satisfied and then the global optimum is obtained [22].

In the chaotic version of imperialist competitive algorithm introduced by Talhatahari et al. [10], in assimilation stage in relation to colonies movement towards imperialist instead of utilizing random values {rand} and U (-1, +1) we use chaotic sequences which are obtained from chaotic maps of Equations (12) and (13). Hence, Equation (9) changes into Equation (14) to update the imperialist position.

$$x = x + \beta \times \{cm\} \otimes \{t - x\} + cm \times \tan(\theta) \times d \times \{v_2\} \tag{14}$$

{cm} and cm are the chaotic sequences obtained from chaotic maps of Equations (12) and (13).

4. 3. Modified Chaotic Orthogonal Imperialist Competitive Algorithm (MCOICA) Performance of chaotic imperialist competitive algorithm has improved through changing and restricting the algorithm. New position of every colony is computed once by Equation (9) and then by Equation (14) in the assimilation. The situation which gives a lower value of cost function is considered as the new situation of the colony. Other stages are performed without any variation. Adding this restriction facilitates the algorithm performance. Figure 4 shows the pseudo-code of modified imperialist competitive algorithm.

1) Initialization of the algorithm. Generate some random solution in the search space and create initial empires.

2) Assimilation: New position of every colony is computed once by (9) and then by (14). The situation which gives a lower value of cost function is considered as the new situation of the colony.

3) Revolution: Random changes occur in the characteristics of some countries.

4) Position exchange between a colony and Imperialist. A colony with a better position than the imperialist has the chance to take the control of empire by replacing the existing imperialist.

5) Imperialistic competition: All imperialists compete to take possession of colonies of each other.

6) Eliminate the powerless empires. Weak empires lose their power gradually and they will finally be eliminated.

7) If the stop condition is satisfied, stop, if not go to 2.

Figure 4. Pseudo-code of modified chaotic orthogonal imperialist competitive algorithm

5. SIMULATION RESULTS

This section investigates the utilization of modified chaotic orthogonal imperialist competitive algorithm in designing IIR digital filters. Then, the results are compared with the results obtained from other evolutionary algorithms. Each algorithm is evaluated for 150 times; minimums, means, maximums and standard deviations of errors are registered. High and low value of the filter coefficients for the system is +2 and -2, respectively. Population, crossover probability, and mutation probability are 80, 0.7, and 0.2, respectively, in the genetic algorithm. For particle swarm optimization algorithm, population is 80; c_1 and c_2 equal to 2.05 and inertia weight is 0.9. Number of countries and imperialists in imperialist competitive algorithm, orthogonal version, and the modified version are 80 and 8, respectively. Probability of revolution occurrence is 0.1. In cuckoo optimization algorithm, initial population of the cuckoos is 5 and maximum number of the cuckoos is 80. Finally, the high and low limits of egg number are considered to be 4 and 2 for each cuckoo, respectively.

Example 1. IIR digital filter and desired filter transfer function come in Equations (15) and (16) [1, 23].

$$H_d[z^{-1}] = \frac{1}{1 - 1.2\,z^{-1} + 0.6\,z^{-2}} \tag{14}$$

$$H[z^{-1}] = \frac{1}{1 - a_1\,z^{-1} - a_2\,z^{-2}} \tag{15}$$

The filters input are a white Gaussian sequence and the input data length is 1000. Iteration number is 100 in each evaluation. Table 1 shows minimums, means, maximums and standard deviations of errors values for different evolutionary algorithms. Figure 5 indicates the comparison of obtained error by the algorithms in 150 evaluations. The obtained results in Table 1 and Figure 5 indicate that modified chaotic orthogonal imperialist competitive algorithm converges in less iteration than other algorithms. In addition, it has less error mean in 150 evaluations.

Example 2. IIR digital filter and desired filter transfer functions come in Equations (17) and (18) [1, 2].

$$H_d\left[z^{-1}\right] = \frac{0.05 - 0.4\,z^{-1}}{1 - 1.1314\,z^{-1} + 0.25\,z^{-2}} \tag{17}$$

$$H\left[z^{-1}\right] = \frac{b_0 + b\,z^{-1} + b_2\,z^{-2}}{1 + a_0\,z^{-1} + a_1\,z^{-2} + a_2\,z^{-3}} \tag{18}$$

The input signal is uniform white sequence taking values in [−1, 1]. Input data length is 200. Number of iteration equals 500 in each evaluation. Table 2 shows minimums, means, maximums and standard deviations of errors for different evolutionary algorithms. Figure 6 shows the comparison of the obtained error by these algorithms 150 evaluations. As Table 2 shows, this example indicates the error obtained from modified chaotic imperialist competitive algorithm is better than other algorithms.

TABLE 1. Results of different algorithms for example 1

Approach	Min	mean	max	SD
GA	1.711 e-030	0.0047983	0.069283	0.011724
COA	1.8349 e-008	3.0631 e-005	0.0003376	4.8187 e-005
PSO	5.6362 e-008	1.3339 e-005	0.0001653	2.2495 e-005
ICA	1.9138 e-019	2.8705 e-010	1.3429 e-008	1.466 e-009
OICA	6.4571 e-021	9.174 e-013	8486 e-011	4.5334 e-012
MCOICA	1.3855 e-030	3.2248 e-020	2.8784 e-018	2.481 e-019

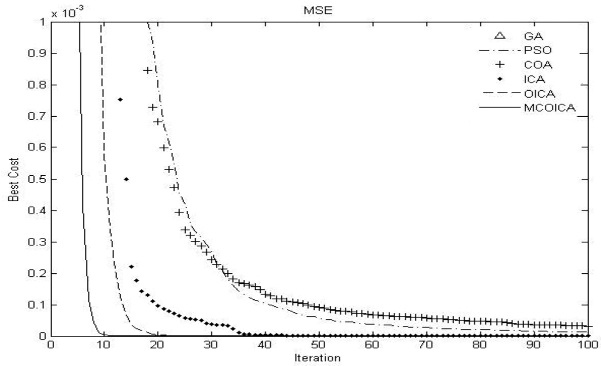

Figure 5. Normalized cost function value versus number of cost function iterations averaged over 150 random runs of different algorithms (Example 1).

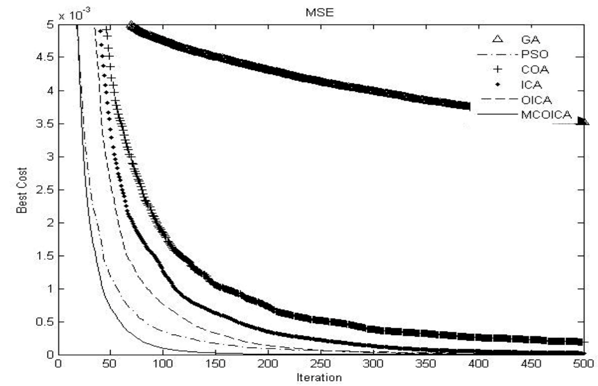

Figure 6. Normalized cost function value versus number of cost function iterations averaged over 150 random runs of different algorithms (Example 2).

TABLE 2. Results of different algorithms for example 2

Approach	Min	mean	max	SD
GA	1.0129 e-005	0.0035217	0.014099	0.0026651
COA	3.8274 e-006	0.00019044	0.0020974	0.00026329
PSO	2.2429 e-007	1.6399 e-005	0.0002904	3.1738 e-005
ICA	1.1541 e-009	2.3803 e-005	0.0007572	6.733e-005
OICA	5.0297 e-011	3.4152 e-006	7.582 e-005	8.6723 e-006
MCOICA	1.0237 e-016	4.2636 e-009	1.7734 e-007	1.6592 e-008

TABLE 3. Results of different algorithms for example 3

Approach	Min	mean	max	SD
GA	0.17012	0.52079	1.3393	0.26065
COA	0.089141	0.2929	1.1648	0.16077
PSO	0.054936	0.19172	1.3145	0.17242
ICA	0.07766	0.25002	0.92951	0.16519
OICA	0.060605	0.19599	0.82022	0.1368
MCOICA	0.053955	0.14153	0.55246	0.089019

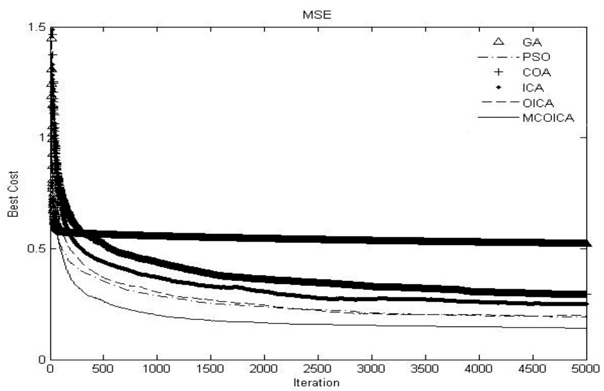

Figure 7. Normalized cost function value versus number of cost function iterations averaged over 150 random runs of different algorithms (Example 3).

Example 3. Equations (19) and (20) show the transfer functions of desired filter and IIR digital filter [1, 23].

$$H_d\left[z^{-1}\right] = \frac{1 - 0.4\ z^{-2} - 0.65\ z^{-4} + 0.26\ z^{-6}}{1 - 0.77\ z^{-2} - 0.8498\ z^{-4} + 0.6486\ z^{-6}} \quad (19)$$

$$H\left[z^{-1}\right] = \frac{b_0 + b_1 z^{-1} + b_2 z^{-2} + b_3 z^{-3} + b_4 z^{-4} + b_5 z^{-5}}{1 + a_1 z^{-1} + a_2 z^{-2} + a_3 z^{-3} + a_4 z^{-4} + a_5 z^{-5}} \quad (20)$$

The system input is a white sequence and the input data length is 100. SNR is 30dB. Iteration number of each evaluation is 5000. Table 3 shows minimums, means, maximums, standard deviations of mean squared error in 150 evaluations for different algorithms. Figure 7 shows the comparison of the obtained error by different algorithms. According to Table 3, modified chaotic orthogonal imperialist competitive algorithm (MCOICA) has better performance than others.

6. CONCLUSION

Modified chaotic orthogonal imperialist competitive algorithm was introduced in the above examples. It was utilized to design IIR digital filter. The obtained results were compared by genetic, cuckoo optimization, particle swarm optimization, imperialist competitive and orthogonal imperialist competitive algorithms. Comparing the error means in 150 times evaluation and investigation of convergence in different repetitions indicates that the modified chaotic orthogonal imperialist competitive algorithm is an appropriate algorithm for designing IIR digital filter and it can be used in designing IIR digital filter.

7.REFERENCES

1. Karaboga, N., "A new design method based on artificial bee colony algorithm for digital iir filters", ***Journal of the Franklin Institute***, Vol. 346, No. 4, (2009), 328-348.
2. Dai, C., Chen, W. and Zhu, Y., "Seeker optimization algorithm for digital iir filter design", ***Industrial Electronics, IEEE Transactions on***, Vol. 57, No. 5, (2010), 1710-1718.
3. Otaru, M.U., Zerguine, A. and Cheded, L., "Channel equalization using simplified least mean-fourth algorithm", ***Digital Signal Processing***, Vol. 21, No. 3, (2011), 447-465.
4. Wu, L. and Qiu, X., "Active impulsive noise control algorithm with post adaptive filter coefficient filtering", ***IET Signal Processing***, Vol. 7, No. 6, (2013), 515-521.
5. Wu, S., Qiu, X. and Wu, M., "Stereo acoustic echo cancellation employing frequency-domain preprocessing and adaptive filter", ***Audio, Speech, and Language Processing, IEEE Transactions on***, Vol. 19, No. 3, (2011), 614-623.
6. Ng, S., Leung, S., Chung, C., Luk, A. and Lau, W., "The genetic search approach. A new learning algorithm for adaptive iir filtering", ***Signal Processing Magazine, IEEE***, Vol. 13, No. 6, (1996), 38-46.
7. Singh, R. and Arya, S.K., "Optimization of iir digital filters using particle swarm optimization", in Communication, Information & Computing Technology (ICCICT), 2012 International Conference on, IEEE. (2012), 1-7.
8. Ghosh, S., Kundu, D., Suresh, K., Das, S. and Abraham, A., "Design of optimal digital iir filters by using a bandwidth adaptive harmony search algorithm", in Nature & Biologically

Inspired Computing,. NaBIC. World Congress on, IEEE. (2009), 481-486.

9. Atashpaz-Gargari, E. and Lucas, C., "Imperialist competitive algorithm: An algorithm for optimization inspired by imperialistic competition", in Evolutionary Computation,. CEC. IEEE Congress on, (2007), 4661-4667.
10. Talatahari, S., Farahmand Azar, B., Sheikholeslami, R. and Gandomi, A., "Imperialist competitive algorithm combined with chaos for global optimization", ***Communications in Nonlinear Science and Numerical Simulation***, Vol. 17, No. 3, (2012), 1312-1319.
11. Tavazoei, M.S. and Haeri, M., "Comparison of different one-dimensional maps as chaotic search pattern in chaos optimization algorithms", ***Applied Mathematics and Computation***, Vol. 187, No. 2, (2007), 1076-1085.
12. Rajabioun, R., "Cuckoo optimization algorithm", ***Applied Soft Computing***, Vol. 11, No. 8, (2011), 5508-5518.
13. Kalinli, A. and Karaboga, N., "Artificial immune algorithm for iir filter design", ***Engineering Applications of Artificial Intelligence***, Vol. 18, No. 8, (2005), 919-929.
14. Luukko, J. and Rauma, K., "Open-loop adaptive filter for power electronics applications", ***Industrial Electronics, IEEE Transactions on***, Vol. 55, No. 2, (2008), 910-917.
15. Kalinli, A. and Karaboga, N., "A new method for adaptive iir filter design based on tabu search algorithm", ***AEU-International Journal of Electronics and Communications***, Vol. 59, No. 2, (2005), 111-117.
16. Karaboga, N., "Digital iir filter design using differential evolution algorithm", ***EURASIP Journal on Applied Signal Processing***, Vol. 2005, (2005), 1269-1276.
17. Krusienski, D. and Jenkins, W., "Particle swarm optimization for adaptive iir filter structures", in Evolutionary Computation, Congress on, IEEE. Vol. 1, (2004), 965-970.
18. Krusienski, D. and Jenkins, W., "Design and performance of adaptive systems based on structured stochastic optimization strategies", ***Circuits and Systems Magazine, IEEE***, Vol. 5, No. 1, (2005), 8-20.
19. Kaveh, A. and Talatahari, S., "Imperialist competitive algorithm for engineering design problems", ***Asian Journal of Civil Engineering***, Vol. 11, No. 6, (2010), 675-697.
20. May, R.M., "Simple mathematical models with very complicated dynamics", ***Nature***, Vol. 261, No. 5560, (1976), 459-467.
21. Parlitz, U. and Ergezinger, S., "Robust communication based on chaotic spreading sequences", ***Physics Letters A***, Vol. 188, No. 2, (1994), 146-150.
22. Yang, D., Li, G. and Cheng, G., "On the efficiency of chaos optimization algorithms for global optimization", ***Chaos, Solitons & Fractals***, Vol. 34, No. 4, (2007), 1366-1375.
23. White, M.S. and Flockton, S.J., Adaptive recursive filtering using evolutionary algorithms, in Evolutionary algorithms in engineering applications., Springer. (1997), 361-376.

Design of IIR Digital Filter using Modified Chaotic Orthogonal Imperialist Competitive Algorithm

RESEARCH NOTE

M. Sharifi[a], H. Mojallali[b]

[a]*Department of Electrical, Computer and Biomedical Engineering, Islamic Azad University, Qazvin Branch, Qazvin, Iran*
[b]*Electrical Engineering Department, Faculty of Engineering, University of Guilan, Rasht, Iran*

PAPER INFO

Paper history:
Received 02June 2013
Received in revised form 04October 2013
Accepted 12December 2013

Keywords:
IIR Digital Filter
Imperialist Competitive Algorithm
Optimization
Evolutionary Algorithm

چکیده

فیلترهای دیجیتال به دو دسته فیلترهای با پاسخ ضربه محدود و فیلترهای با پاسخ ضربه نامحدود تقسیم می‌شوند. فیلترهای IIR به دلیل اینکه در مقایسه با فیلترهای FIR می‌توانند مرتبه فیلتر را به طور قابل ملاحظه‌ای کاهش دهند، بیشتر مورد توجه قرار گرفته‌اند. در طراحی فیلترهای دیجیتال IIR، به دلیل داشتن سطح خطای چندوجهی، تکنیک‌های بهینه‌سازی ساده و قدرتمند برای اجتناب از مینیمم محلی مورد نیاز هستند. الگوریتم رقابت استعماری یک الگوریتم تکاملی است که در سال‌های اخیر در حل مسائل بهینه‌سازی مورد استفاده قرار گرفته است و می‌تواند پاسخ بهینه کلی را در یک فضای جستجوی غیرخطی پیدا کند. در این مقاله، با ایجاد تغییراتی، عملکرد الگوریتم رقابت استعماری متعامد آشوبی بهبود داده شده است و این الگوریتم بهبودیافته در طراحی فیلتر دیجیتال IIR مورد استفاده قرار گرفته و عملکرد آن با عملکرد چند الگوریتم تکاملی مقایسه شده است.

doi:*10.5829/idosi.ije.2014.27.07a.04*