Volume 5, Issue 6, June 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Craziness Based Particle Swarm Optimization Algorithm for Digital Band Pass FIR Filter

Beant Singh, Darshan Singh
Department of Electronics & Communication Engineering, Punjab Technical University,
Giani Zail Singh Campus, Bathinda, Punjab, India

Abstract: In this paper, an optimal design of linear phase digital band pass FIR filter using craziness based particle swarm optimization (CRPSO) algorithm, has been studied. FIR filter design is a multi-modal, multi-dimensional optimization problem. The traditional gradient based optimization techniques are not efficient for such optimization problem as they may get trapped on local optima. CRPSO algorithm gives us set of optimal filter coefficients and tries to meet the required specifications. In birds flying and fish schooling, a bird and fish suddenly changes its direction it is due to word "craziness". This is discussed by making the use of CRPSO algorithm. In this paper, CRPSO based optimal FIR band pass filters has been performed on different orders of filter to get minimum optimal best order, and further changes in different parameters are done on the best order filter. In this paper, design of band pass FIR filter using CRPSO algorithm to minimize the magnitude error of digital FIR filter and to minimize ripple magnitude error in pass band and stop band have been studied.

Keywords: Finite Impulse response (FIR) Filter, infinite Impulse Response (IIR), Particle Swarm Optimization (PSO), Craziness Based Particle Swarm Optimization (CRPSO).

I. INTRODUCTION

Digital Filters are important part of digital signal processing (DSP) system. Digital filters are used for large number of applications few are, systems for audio and video processing, communication system, image processing, medical field, pattern recognition etc. Digital filter can be implemented in both hardware as well software and can process both real time and off line signals. Digital filer has inherent advantages like small physical size and reliability. Digital filtering can be applied to very low frequency signals. There are mainly two types of filters. They are Finite Impulse Response (FIR), Infinite Impulse Response (IIR) [1]. FIR filter commonly known as non-recursive [4] and IIR known as recursive filters. Implementation of FIR filter is easy, but it is slower as compare to IIR, but there are number of advantages of FIR filters as they shows linear phase response, an attractive choice because of ease in design and stability and their response is better. There are different techniques for the design of FIR filter and for its implementation [11]. Out of these, window method is most popular because in this method, ideal impulse response is multiplied with a window function. There are various kinds of window methods [11] some of them are (hamming, hanning, Kaiser, butterworth, chebyshew [10] etc), these are depending upon the requirements of ripples on the pass and stop band attenuation. But windows methods do not have sufficient control of frequency response this was one of the drawback of windows functions.

There are different optimization algorithms such as simulated annealing algorithm [3], genetic algorithm [9], standard GA (named as Real Coded GA (RGA)), Novel Particle Swarm Optimization (NPSO), Particle Swarm Optimization (PSO), Craziness Based Particle Swarm Optimization (CRPSO) etc. Genetic algorithm (GA) has been widely used algorithm for design methods and has capability of satisfying constraint. Genetic algorithm (GA) is also better in obtaining near global optimum solution but Real Coded GA (RGA) has good performance over GA.

In this paper the approach studied takes the advantages of Particle Swarm Optimization (PSO) algorithm. Particle Swarm Optimization (PSO) algorithm is a kind of evolutionary algorithm developed by Kennedy and Eberhart (1995) [5], Eberhart and Shi (2000) [3]. The PSO is easy to implement because its convergence can be controlled via few parameter. But there are some drawback such as it may be influenced by premature convergence and stagnation problem [2,6]. To overcome these limitations of PSO algorithm has been modified and as Craziness Based Particle Swarm Optimization (CRPSO). In this paper Craziness Based Particle Swarm Optimization (CRPSO) algorithm has been employed for band pass digital FIR filter. Craziness Based Particle Swarm Optimization (CRPSO) algorithm tries to find the best coefficient that closely matches the desired frequency response. CRPSO improves the results of PSO.

II. BAND PASS FIR FILTER DESIGN

A digital FIR filter is characterized by

$$H(z) = \sum_{k=0}^{M} h(n) z^{-k} \tag{1}$$

where k=0, 1, 2, 3……..N

Where M is order of filter, (M+1) are the number of coefficients, h (n) is filter impulse response. The value of h (n) depends upon the type of filter e.g. Low pass, Band pass, and High pass etc.

Coefficient of an FIR filter has linear phase if its unit sample response satisfied the following condition:

$$h(n) = \pm h(M-1-n) \quad (2)$$

+ = symmetric

- = anti symmetric

The frequency the response of FIR digital filter can be calculated as:

$$H(e^{jwk}) = \sum_{n=0}^{N} h(n) e^{-jw_k n} \quad (3)$$

where $w_k = 2\pi k/N$; $H(e^{jwk})$ is a Fourier transform complex vector. This is FIR filter frequency response. The frequency is sampled in $[0, \pi]$ with N points. The absolute error and squared error of magnitude response as defined as below

$$e_1(x) = \sum_{i=0}^{k} \left| H_d(\omega_i) - |H(\omega_i, x)| \right| \quad (4)$$

$$e_2(x) = \sum_{i=0}^{k} \left(\left| H_d(\omega_i) - |H(\omega_i, x)| \right| \right)^2 \quad (5)$$

The desired magnitude response $H_d(\omega_i)$ is given as:

$$H_d(\omega_i) = \begin{cases} 1 & ;\text{for } \omega_i \in \text{passband} \\ 0 & ;\text{for } \omega_i \in \text{stopband} \end{cases} \quad (6)$$

The ripple magnitudes of pass band $\delta_1(x)$ and stop band $\delta_2(x)$ are given as ;

$$\delta_1(x) = \max_{\omega_i}\{|H(\omega_i, x)|\} - \min_{\omega_i}\{|H(\omega_i, x)|\}; \quad \omega_i \in \text{passband} \quad (7)$$

and

$$\delta_2(x) = \max_{\omega_i}\{|H(\omega_i, x)|\};$$

$$\omega_i \in \text{stopband} \quad (8)$$

All objectives are included and the multicriterion optimization problem is stated as:

Minimize $O_1(x) = e_1(x)$ (8a)

Minimize $O_2(x) = e_2(x)$ (8b)

Minimize $O_3(x) = \delta_1(x)$ (8c)

Minimize $O_4(x) = \delta_2(x)$ (8d)

In multiple-criterion constrained optimization problem for the design of digital IIR filter a single optimal tradeoffs point can be found by solving following:

$$\text{Minimize } f(x) = \sum_{j=1}^{4} w_j f_j(x) \quad (9)$$

III. EVOLUTIONARY TECHNIQUE EMPLOYED

A. Particle Swarm Optimization (PSO)

PSO was introduced by Kennedy and Eberhant in 1995. Particle swarm optimization algorithm is inspired by social behaviour moment dynamic of insect, birds, fish. PSO algorithm successfully applied to wide variety of problems such as neutral network, structural optimization, shape topology optimization etc. PSO algorithm is simple for implementation, derivative free, very few algorithm parameters and is very efficient global search algorithm. PSO is flexible, robust population based search optimization technique [7,8]. PSO concept is similar to the behaviour of the swarm of birds. It is developed through simulation of bird floating in space, bird flocking optimization as criteria of object function. Each particle (bird) knows its best value (P best) so far in the group (g best). Next each particle tries to modify or changing its position using information such as the distance between the current position and p best, the distance between the current position and g best.

Mathematically velocity of particle vector is according to equation.

$$V_i^{(k+1)} = w * V_i^{(k)} + C1 * rand_1 * \left\{pbest_i^{(k)} - S_i^{(k)}\right\} + C2 * rand_2 * \left\{gbest^{(k)} - S_i^{(k)}\right\} \quad (10)$$

where Vi is the velocity of ith particle at kth iteration w is weighting function, C1 and C2 are acceleration constant, rand1 and rand2 are random number between 0 and 1, $S_i^{(k)}$ is current position of ith particle vector at kth iteration, $pbest_i^{(k)}$ is personal best of ith particle vector at kth iteration, $gbest^{(k)}$ is group best at kth iteration

The searching point in solution space may be modified by the equation

$$S_i^{k+1} = S_i^k + V_i^{k+1} \quad (11)$$

The first term of Eq.10 is the previous velocity of particle vector. But second and third terms are used to change the velocity of the particle. Without these second and third terms, the particles will keep on flying in the same direction until it hits the boundary.

B. Craziness based Particle Swarm Optimization (CRPSO)

CRPSO method is originated from PSO. The modified PSO is term as CRPSO has a special feature like sudden change velocity, craziness factor and change of direction of flying to words an apparently non promising area of food depends upon the particle mood.

The velocity in this case expressed as[7]:

$$V_i^{(k+1)} = r_2 * sign(r_3) * V_i^{(k)} + (1 - r_2) * C_1 * r_1 * \{pbest_i^{(k)} - S_i^{(k)}\} + (1 - r_2) * C_2 * (1 - r_1) * \{gbest^{(k)} - S_i^{(k)}\} \quad (12)$$

where r1, r2, r3, are random parameters uniformly taken from interval (0, 1) and sign (r3) is a function defined as :
Sign (r3) = -1 where r3 ≤ 0.05
= 1 where r3 >0.05 (13)

$rand_1$ and $rand_2$ are two independent parameters that are used in PSO. If both are small then both the social and personal experiences are not used full and convergence speed is reduced. So instead of using independent parameters single parameter is used so r_1 is large and 1-$rand_1$ is small and vice-versa. To control the balance between global and local searches, another random parameter rand2 is introduced.

A bird may not change its position due to inertia, they fly towards a region at which they thinks is most promising for food. In birds flocking or fish schooling, a bird or fish often changes directions suddenly. This is described by using a "craziness" variable. A craziness operator is introduced in the proposed technique to ensure that the particle would have a predefined craziness probability to maintain the diversity of the particles. Consequently, before updating its position the velocity of particle is crazed by

$$V_i^{(k+1)} = V_i^{(k+1)} + P(r_4) * sign(r_4) * v^{craziness} \quad (14)$$

$P(r_4) = 1$ when $r_4 \leq PCR$
$= 0$ when $r_4 > PCR$ (15)
Sign $(r_4) = -1$ when $r_4 \geq 0.5$
$= 0$ when $r_4 < PCR$ (16)

where r_4 is random parameter which is chosen uniformly within the interval [0, 1]; where $v^{craziness}$ is a random parameter and PCR is a predefined probability of craziness.

IV. SIMULATION RESULTS AND DISCUSSIONS

The digital FIR band pass filter has been designed by evaluating the filter coefficients by using craziness based particle swarm optimization (CPRSO) algorithm. Initially order of filter has been taken as 20 in this design problem and only half of the filter coefficients have been calculated because FIR filter shows the symmetric property. To design digital FIR band pass filter based on CRPSO algorithm 100 runs have been taken with 200 iterations in each run. 200 equally spaced samples are set to design desired filter. The range of pass band has been taken as 0.4 π < $0.4\pi \leq \omega \leq 0.6\pi$ and stop band have been taken as $0 \leq \omega \leq 0.25\pi$ and $0.75\pi \leq \omega \leq \pi$. Initially the population size value 100, acceleration constant (C1&C2) values 2.0, craziness factor (VCRZ) value 0.00001 and predefined probability of craziness (PCR) value 0.3 has been taken for filter order 20

Table 1 Parameter used for design of optimal linear phase fir band pass filter using crpso

Parameters	**CRPSO Values**
Population size	100
Iteration cycle	200
Acceleration constant (C1)	2.0
Acceleration constant (C2)	2.0
Predefined probability of craziness (PCR)	0.3
Craziness Factor (VCRZ)	0.00001
Error (ERR)	0.0001
Max Iteration	200
W1 minimum	0.1
W1 maximum	0.4

These are the parameters used for the design of optimal linear phase FIR band pass filter by using CRPSO algorithm.

A. Selection of filter Order

Filter Order has been taken from 20 to 32 for the CRPSO algorithm and objective function is obtained. The Fig. 1 shows objective function variations with respect to filter order.

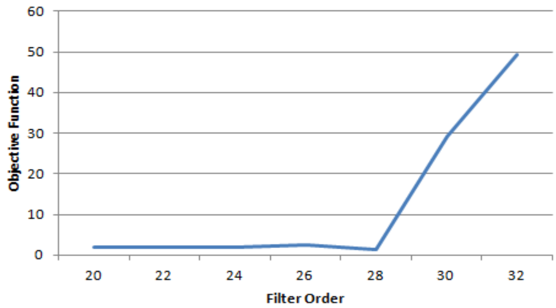

Figure 1: Graph of Objective Function vs filter Order

Fig.1 shows that with the increase of filter order objective function decreases continuously and gives the minimum value of objective function at order 28 and then after this objective function starts increasing with increase in filter order. So order 28 has been selected for the design of digital band pass FIR filter. Now the values of control parameters of CRPSO algorithm have been varied to obtain the optimal results by doing data generation again at the filter order 28 with varying values of population.

Population size has been varied from 60 to 150 by keeping filter order 28 and the observed values of objective function at different populations are shown in Table 2.

Table 2: Objective function variation at different population size values

Sr. No.	Population Size	Objective Function
1	60	1.127405
2	70	1.126615
3	80	1.127445
4	90	1.127455
5	100	1.126385
6	110	1.633345
7	120	1.645485
8	130	1.913608
9	140	1.914372
10	150	1.968859

The Table 2 shows the minimum value of objective function at population value at 100. Graph is drawn which shows the trend of objective function variations with respect to population size.

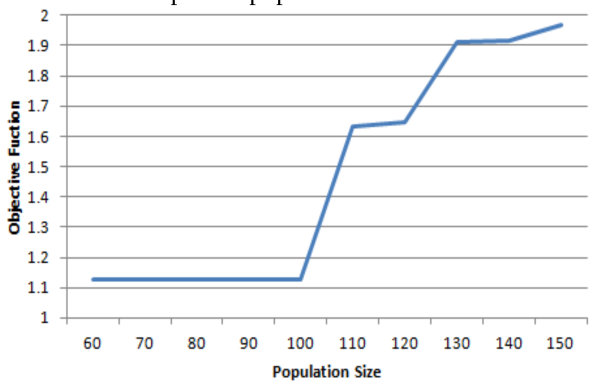

Figure 2: Graph of filter order achieved value vs population size

The Fig.2 shows that the objective function value decreases with increase in population size value up to 100 after this objective function start increasing up to population size value 150. But the population size value 100 gives the best results for CRPSO algorithm.

Now the impact of changed values of acceleration constant (C1 & C2) on the objective function has been studied as shown in Table 3.

Table 3 Objective function variations at different acceleration constants (c1 & c2) values

Sr. No.	Acceleration constants	Objective Function
1	1.50	0.905005
2	1.75	0.904233
3	2.00	0.904160
4	2.25	0.904225
5	2.50	0.904459
6	2.75	0.906067
7	3.00	0.912842

The effective range of C1 & C2 is between 1.50 and 3 by keeping population fixed at 100. The values of C1 & C2 should be taken same. The Table3 shows that acceleration constant (C1 & C2) at value 2.00 gives minimum value of objective function. So now plot is drawn to show the variations of objective function with respect to the acceleration constant (C1 & C2) values.

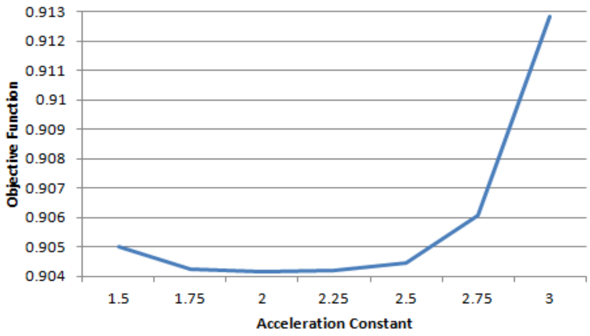

Figure 3: Graph of Acceleration Constant (C1 & C2) vs Objective Function

From the Figure 3 it is observed that CRPSO algorithm at C1 & C2 value 2.00 gives the minimum value of objective function.

Now value of craziness factor (VCRZ) has been changed from 0.00001 to 0.00005 with fixed values of C1&C2 at 2.00 and Population size 100. The observed values of objective functions are shown in Table 4.

Table 4 Objective function for different values of craziness factor (vcrz)

Sr. No.	Craziness Factor (VCRZ) Values	Objective Function
1	0.000004	0.904053
2	0.000005	0.904050
3	0.00001	0.904160
4	0.00002	0.904209
5	0.00003	0.904357
6	0.00004	0.904498
7	0.00005	0.904505

The Table 4 shows that Craziness Factor (VCRZ) at Value 0.0000040 gives the minimum value of objective function. Now the plot is drawn to show the variations of objective function with respect to the Craziness Factor (VCRZ) Values.

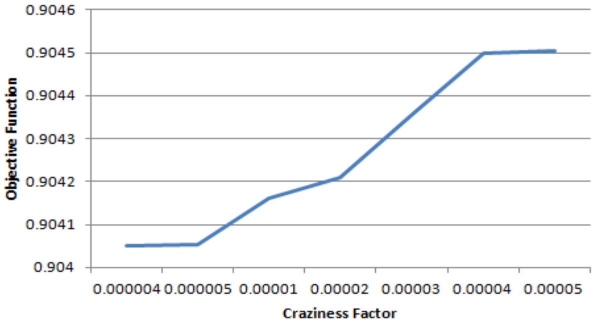

Figure 4: Graph of Craziness Factor (VCRZ) Values vs Objective Function

From the Fig. 4 it has been observed that at VCRZ value 0.0000040 algorithms gives the best results. Now by fixing the value of craziness factor (VCRZ), the values of Predefined probability of craziness (PCR) varies from 0.04 to 0.5 as shown in Table 5.

Table 5 Objective function for different values of predefined probability values of craziness (pcr)

Sr. No.	Predefined probability of craziness (PCR)	Objective Function
1	0.04	0.832840
2	0.05	0.832798
3	0.1	0.832855
4	0.2	0.832923
5	0.3	0.832933
6	0.4	0.833048
7	0.5	0.832798

The Table 5 shows that Predefined probability of craziness (PCR) at Value 0.05 gives the minimum value of objective function. Now the plot is drawn to show the variations of objective function with respect to the Predefined probability of craziness (PCR).

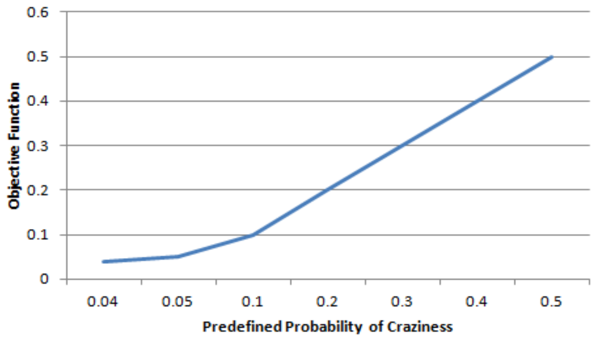

Figure 5 Predefined probability of craziness vs Objective Function

B. Analysis of Magnitude and Phase Response of Band Pass Digital FIR Filter

The calculated results have been performed on MATLAB. Order of filter have been selected as 28 which results in number of coefficients as 29.

Table 6 Calculated filter coefficients

h(n)	CRPSO coefficients
h (0)=h(28)	-.010317
h(1)=h(27)	-.001993
h(2)= h(26)	.011336
h(3)= h(25)	.000445
h(4)= h(24)	.017837
h(5)= h(23)	.002860
h(6)= h(22)	-.052783
h(7)= h(21)	-.002730
h(8)= h(20)	.022903
h(9)= h(19)	-.001363
h(10)= h(18)	.110525
h(11)= h(17)	.004120
h(12)= h(16)	-.281746
h(13)= h(15)	-.002199
h(14)	.361097

From these coefficients frequency response has been obtained. Magnitude is analyzed to show amplification and attenuation values for the different frequency range. Magnitude response of band pass filter having coefficients shown in table 6 is depicted in fig.6.

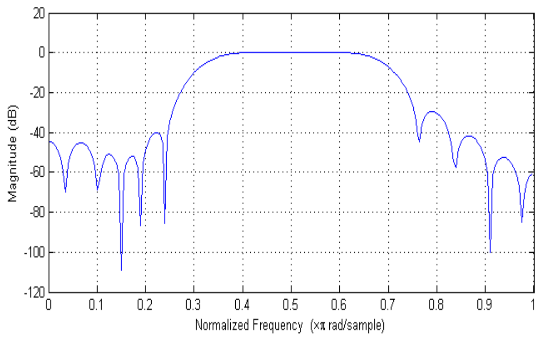

Figure 6: Magnitude vs Normalized Frequency

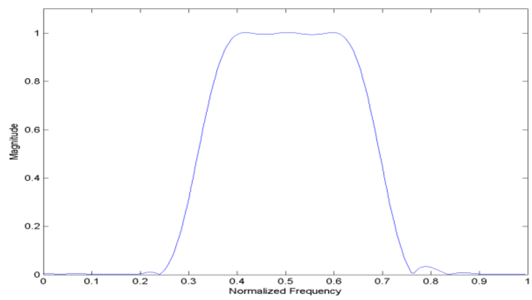

Figure 7: Magnitude response of High Pass Digital FIR Filter

Hence Fig.7 indicates that the frequencies that lie in stop band range are attenuated and that lies in pass band range are passed.

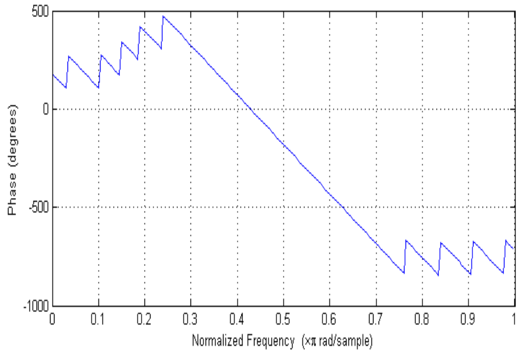

Figure 8: Phase vs Normalized Frequency

The Fig. 8 shows that filter have linear phase response in pass band and transition band.

Table 7 Maximum, minimum, average objective function and standard deviation

Sr. No.	Maximum Value	Minimum Value	Average Value	Standard Deviation
1	.877318	.832798	.840409	.008201

Table 7 shows that value of standard deviation is very much less than 1 which represents the robust nature of filter.

V. CONCLUSION

CRPSO algorithm is very powerful optimization algorithm that exhibits simplicity and robustness using control parameters. Control parameters have great impact on the objective function values. In this thesis order of filter is varied from 20 to 32 and the best value of objective function is obtained at filter order 28. Then the control parameters have been varied to obtain the optimum results for the designed CRPSO algorithm. Hence the calculated results show that optimum value of objective function for the designed digital band pass FIR filter has been obtained at filter order 28 with population value 100, C1 & C2 value 2.00, Craziness Factor (VCRZ) value 0.000004 and Predefined probability of craziness (PCR) value 0.05. Magnitude and phase plot have been observed for the designed digital band pass FIR filter. The same algorithm can also be applied to design other three types of filters.

REFERENCES

[1] Litwin L, (2000) "FIR and IIR digital filters", IEEE Potentials, vol. 19(4), pp. 28-31.

[2] Biswal, B., Dash, P.K., Panigrahi and B.K., (2009). "Power quality disturbance classification using fuzzy C-means algorithm and adaptive particle swarm optimization" IEEE Trans. Ind. Electron. vol. 56 (1), pp. 212–220.

[3] Chen, S., (2000) "IIR Model identification using batch-recursive adaptive simulated annealing algorithm", In: Proceedings of 6th Annual Chinese Automation and Computer Science Conference. pp. 151–155.

[4] Herrmann and O. Schussler (1970) "Design of non-recursive digital filters with linear phase" Electron. Lett. vol. 6, pp 329–330.

[5] Kennedy, J. Eberhart, (1995) "Particle swarm optimization" In:Proc. IEEE Int.Conf.Neural Network, pp. 1942-1948.

[6] Ling, S.H., Iu, H.H.C., Leung, F.H.F., Chan, K.Y., (2008) "Improved hybrid particle swarm optimized wavelet neural network for modeling the development of fluid dispensing for electronic packaging" IEEE Trans. Ind. Electron. vol. 55 (9), pp 3447–3460.

[7] Mandal, Ghoshal, S.P., Bhattacharjee, A.K., (2010) "Radiation pattern optimization for concentric circular antenna array with central element feeding using craziness based particle swarm optimization" In: International Journal of RF and Microwave Computer-Aided Engineering, vol. 20(5), John Wiley & Sons, Inc.,pp. 577–586 (September).

[8] Mandal, Ghoshal, S.P., Bhattacharjee, A.K., (2009), "Comparative optimal designs of non-uniformly excited concentric circular antenna array using evolutionary optimization techniques", In:IEEE Second International Conference on Emerging Trends in Engineering and Technology, ICETET vol. 09. pp. 619–624.

[9] Mastorakis, N.E., Gonos, I.F., Swamy, M.N.S., (2003), "Design of two dimensional recursive filters using genetic algorithms", IEEE Trans.Circ. Syst. I – Fundam, vol. 50, pp 634–639.

[10] Parks, T.W., McClellan, J.H., (1972),"Chebyshev approximation for non recursive digital filters with linear phase" IEEE Trans. Circ. Theory CT-19, pp. 189–194.

[11] Yuksel, Ozbay., Bekir, Karlik., Kavsaoglu, Resit, A., (2003), "A windows-based digital filter design", Math. Compute. vol. 8 (3), pp 287–294.

