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Optimal FIR Filter Design using GWO Algorithm

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Abstract: In the given paper an optimal design of FIR digital filter using Grey Wolf Optimization (GWO) algorithm has been presented. The basic idea behind this algorithm is to provide comparatively competitive results with that of rest of the algorithms by not stagnating to the local minima. The proposed algorithm is used to design the FIR low pass and high pass filter. Comparison has been done with other pre-existing algorithms and results proved that GWO algorithm outperformed filter coefficients, maximum stop band and pass band ripple and maximum stop band attenuation is taken into an account.

Keywords: Filter coefficients, magnitude response, PSO, GWO.

I. Introduction

Digital Filters are very crucial part of digital signal processing (DSP) system. They are used in various different applications including, systems for video as well as audio processing, image processing, communication system, medical field etc. In control system, noise is mixed in the signal at input side, and influence the performance of the given system to a greater extent. This is the reason, filtering is necessary for and input signal to get the desired useful signal. There are two types of digital filters i.e. Finite Impulse Response (FIR) and Infinite Impulse Response (IIR). [1] The FIR filter has a very crucial role in the processing of digital signal. This is because of its qualities like linear phase, stability and ease of design. Various classical methods were used for designing FIR filters including window method, frequency sampling method etc.[2]. The window method proved to be the simplest method among all in which the window function is multiplied with the desired impulse response of FIR filter. Various types of window functions such as Chebyshev [3] Kaiser, and Hamming are used for the efficient design of FIR filters which depends on specifications of filter. The Remez exchange algorithm revealed by Park and McClellan [4] was found to be superior to that of all other pre existing traditional methods. But it has disadvantage like high pass band ripple as well as computational complexity [5]. With the more advancement in techniques for designing filter, the new evolutionary algorithms were found to play an important role. Those algorithms were inspired by the social behavior of the individual.

Different evolutionary algorithms like genetic algorithm (GA) [6] [7] [8], simulated annealing [9], artificial bee colony algorithm (ABC) [10], tabu search [11], Differential algorithm [12], Real Coded Genetic Algorithm (RCGA) [13], Teaching-Learning technique [14], Heuristic methods [17] were used for efficient design of optimal digital filters. In order to enhance the performance of such evolutionary algorithms by taking into consideration about the revisiting of solution again and again, stagnation issues at local minima, new GWO algorithm was designed. In this paper a GWO algorithm has been used for the designing of optimal digital FIR low pass and high pass filter.

II. Grey Wolf Optimization Algorithm

Grey Wolf optimization algorithm (GWO) is inspired by the social behavior of grey wolves which belongs to Canidae family. Also these are considered at the top of the food chain and prefer to live in packs in which alpha (α) wolves are responsible for taking any type of decision about hunting or tracking strategy and is dictated to the other members of a pack including beta, delta as well as omega wolves where beta are the subordinate wolves that helps alpha in taking any decision. Omega comes in lowest ranking of grey wolves and delta wolves dominate omega wolves [25].

Main phases of grey wolf hunting are:

1. Tracking, chasing and approaching the prey.
2. Pursuing, encircling and harassing the prey until it stops moving.
3. Attacking the prey.

III. Mathematical Model

A. Social hierarchy:

In this the fittest solution is known as the alpha, the second and third best solutions are named beta and delta respectively. The rest of the candidate solutions are assumed to be omega.

B. Encircling prey

Grey wolves encircle prey during the hunt. In order to mathematically model encircling behavior the following equations are proposed:

$$\vec{D} = |\vec{C} \cdot \vec{X}_p(t) - \vec{X}(t)|$$

$$\vec{X}(t+1) = \vec{X}_p(t) - \vec{A} \cdot \vec{D}$$

where t indicates the current iteration, A and C are coefficient vectors, X_p is the position vector of the prey, and X indicates the position vector of a grey wolf.

C. Hunting

In order to mathematically simulate the hunting behavior of grey wolves, we suppose that the alpha (best candidate solution) beta, and delta have better knowledge about the potential location of prey. Therefore, we save the first three best solutions obtained so far and oblige the other search agents (including the omegas) to update their positions according to the position of the best search agents[25]. The following formulas are proposed in this regard.

$$\vec{D}_\alpha = |\vec{C}_1 \cdot \vec{X}_\alpha - \vec{X}|$$

$$\vec{D}_\beta = |\vec{C}_2 \cdot \vec{X}_\beta - \vec{X}|$$

$$\vec{D}_\delta = |\vec{C}_3 \cdot \vec{X}_\delta - \vec{X}|$$

$$\vec{X}_1 = \vec{X}_\alpha - \vec{A}_1 \cdot \vec{D}_\alpha$$

$$\vec{X}_2 = \vec{X}_\beta - \vec{A}_2 \cdot \vec{D}_\beta$$

$$\vec{X}_3 = \vec{X}_\delta - \vec{A}_3 \cdot \vec{D}_\delta$$

$$\vec{X}(t+1) = \frac{\vec{X}_1 + \vec{X}_2 + \vec{X}_3}{3}$$

D. Attacking Prey

In order to mathematically model approaching the prey we decrease the value of a. In other words A is a random value in the interval $[-2a, 2a]$ where 'a' is decreased from 2 to 0 over the course of iterations.

IV. Problem Formulation

The mathematical expression for digital FIR filter is:

$$H(z) = \sum_{n=0}^N h(n) z^{-n}, n=0,1..N$$

where N is the order of the filter which has (N+1) number of coefficients. h(n) is the filter's impulse response. The type of the filter e.g. low pass, high pass, band pass etc. is judged by considering the values of h(n). In any filter design, it is the basic idea to attain the characteristics of the proposed filter as close as possible to the desired ideal FIR filter. However the ideal digital filter design is almost impossible and for this reason we try to minimize the number of ripple in the pass band as well as stop attenuation is considered as the main criteria for any filter design.

V. Simulation Results

In this paper low pass and high pass FIR filter of order 20 are designed using GWO. The specifications of low pass and high pass FIR filter are given below:

Table 1 Filter specifications

Parameters	LP filter	HP filter
Pass band frequency	0.45π	0.62π
Stop band frequency	0.55π	0.87π

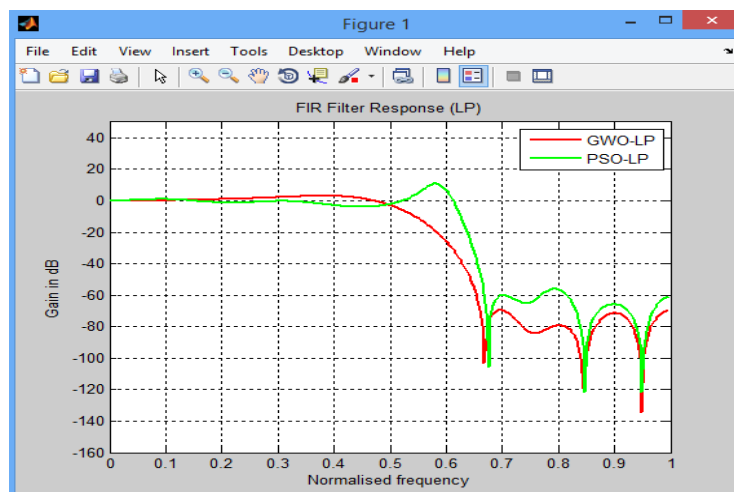


Figure 1 Magnitude response of FIR LP filter using GWO

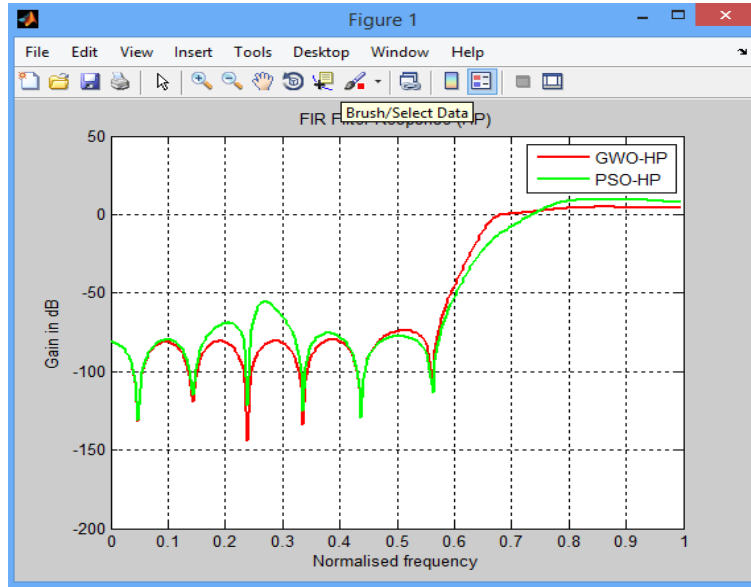


Figure 2 Magnitude response of FIR HP filter using GWO

Table 3 Coefficients of LP filter

Coefficients	PSO	GWO
$h(1)=h(21)$	0.2696	0.0486
$h(2)=h(20)$	0.3978	0.0826
$h(3)=h(19)$	0.3440	0.3907
$h(4)=h(18)$	0.2663	0.1.66
$h(5)=h(17)$	0.3978	-0.4475
$h(6)=h(16)$	0.4438	0.0877
$h(7)=h(15)$	0.2693	0.3590
$h(8)=h(14)$	0.3974	-0.9906
$h(9)=h(13)$	0.2677	0.4399
$h(10)=h(12)$	0.4501	0.4700
$h(11)$	0.3977	0.1847

Table 4 Other specifications of LP filter.

Algorithm	Maximum pass band ripple	Maximum stop band ripple	Maximum stop band attenuation
PSO	0.47	0.67	27.359
GWO	0.32	0.44	38.89

In table 3 the optimized coefficients for band stop filter of order 20 has been calculated using GWO and compared with the coefficients achieved by using PSO. For the simplicity the coefficients calculated in has been round off to the four places only. The GWO gave more optimized coefficients as obtained by other algorithm. In table 4 the other performance parameters like maximum stop band, pass band ripple and stop band ripple has been calculated by using GWO and compared with PSO. The results showed that the GWO outperform in terms of maximum stop band attenuation than other algorithms.

Table 5 Coefficients of HP filter

Coefficients	PSO	GWO
$h(1)=h(21)$	0.2693	0.0115
$h(2)=h(20)$	0.3998	0.0282
$h(3)=h(19)$	0.2739	0.1030
$h(4)=h(18)$	0.2688	0.4004
$h(5)=h(17)$	0.3996	0.2881
$h(6)=h(16)$	0.5835	0.1538

h(7)=h(15)	0.2685	0.2686
h(8)=h(14)	0.3978	0.7349
h(9)=h(13)	0.3152	0.1884
h(10)=h(12)	0.2674	0.9468
h(11)	0.3977	0.0940

In table 5 the optimized coefficients for high pass filter of order 20 has been calculated using GWO and compared with the coefficients obtained by using PSO. The GWO gave more optimized coefficients as compared to the coefficients obtained by other algorithm.

Table 6 Other specifications of HP filter

Algorithm	Maximum pass band ripple	Maximum stop band ripple	Maximum stop band attenuation
PSO	0.74	0.34	24.03
GWO	0.46	0.12	31.67

In table 6 the other performance parameters like maximum stop band, pass band ripple and stop band ripple has been calculated by using GWO and compared with PSO. The results showed that the GWO outperform in terms of maximum stop band attenuation, and give minimum ripple in pass band and stop band than other algorithm.

V. Conclusion

This paper presents the novel and optimal method for the designing of low pass and high pass filter using GWO algorithm. Comparison of the results of GWO with other pre-existing algorithms has been done. The simulation results clearly indicate that GWO demonstrates the best performance in terms of magnitude response, minimum stop band ripple , minimum pass band ripple and maximum stop band attenuation.

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