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DESIGN OF OPTIMUM LINEAR PHASE LOW PASS FIR FILTER USING HYBRID PSO AND GSA EVOLUTIONARY ALGORITHM

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ABSTRACT: The digital filters play an important role in the field of science and technology. Due to phase linearity and stability digital FIR filters are used in number of applications. The various design technology are developed for the designing of the digital filters using evolutionary techniques like particle swarm optimization(PSO), genetic algorithm(GA), differential evolution(DE) etc. and the modified version of these. In this paper design of digital Low pass FIR filter is presented using hybrid PSO and gravitational search algorithm (GSA) algorithm. PSOGSA uses the capability of exploration and exploitation of GSA and PSO respectively. In this paper the desired filter specification are tried to achieve with this algorithm and the simulation results have been compared with GA and MPSO algorithms. The simulation results reveal that the proposed design method for FIR low pass filter using PSOGSA is better than the GA and MPSO in terms of optimization of filter coefficients as well as convergence rate

I. INTRODUCTION

The main function of Digital filters is to eliminate the noise and fetched out the useful signal from other unwanted signals. It is a fundamental device used in almost every digital signal processing application. They are used in many applications such as biomedical, military, speech and audio, image processing etc. There are many advantages of digital filters over the analog filter like versatility, repeatability, accuracy, signal can be stored, flexibility, portability etc. besides these advantages the digital filters produce linear phase response and are inherently stable rather than in case of analog filters. The hardware of digital filter can also be reduced using VLSI technology. Depending on the impulse response Digital filters are classified into two categories the first is FIR (Finite Impulse Response) filters and the second is the IIR (Infinite Impulse Response) filters. FIR filters are also called non- recursive filters since they do not use feedback. The IIR filters possess non-linear phase response and also the digital filter become less stable. The main benefits of FIR filters over IIR filters is that they have linear phase and stable which makes FIR filters as a powerful component in the most of the applications of science and technology. Different techniques are used for the designing of digital FIR filter such as window method, frequency sampling and others. The Parks and McClellan proposed Remez exchange algorithm [1] which is better than all the above traditional methods. The most used method is the window method which is finite duration of coefficients which is used to achieve the desired objectives. With the evolution of evolutionary algorithms the design methodology of digital filters has been changed to greater extent. The various evolutionary techniques are used by various researchers for the design of filters. The different evolutionary techniques are PSO, GSA, GA, DE, Cuckoo Search algorithm etc. The various modified and hybrid algorithms are also used for the designing of filters. The cuckoo Search algorithm is used for the FIR filter is explained in [2]. This algorithm is inspired by the breeding behavior of cuckoos. This algorithm provides fast convergence. The design of PSO using constriction factor approach for non-linear, non-differential, multi-model LP FIR filter is proposed in [3]. With the help of Particle Swarm Optimization with Constriction Factor and Inertia Weight Approach (PSO-CFIWA) for the designing of the digital HP FIR filter of different orders is explained in [4]. The new method on the design of FIR digital filters based on chaotic mutation particle swarm optimization (CPSO) based on local searching, which improves the performance of the standard PSO. The hybrid of GA and PSO based design of Digital LP FIR filter is explained in [5]. In this individuals in a new generation are created, not only by crossover and mutation operation as in Genetic algorithm, but also by Particle swarm optimization. The algorithm is used for the designing of FIR LP filter using various windows. The design of Digital FIR filter using Genetic algorithm is proposed in [6]. Differential algorithm based design of FIR filter is proposed in [7] which is used for Pulse shaping filter in a QPSK modulated system. The proposed filter performance is compared with standard RC and RRC pulse shaping filters which offered fast convergence speed. The design of Digital FIR Filter Using Hybrid Random Particle Swarm Optimization with Differential Evolution is explained in [8]. The simulation results show the superiority of RPSODE in global convergence properties and local search ability. The Digital FIR filter design using fitness based hybrid adaptive differential evolution with particle swarm optimization is proposed in [13] in which ADEPSO overcome the individuals disadvantages like instability problem of DE and the problem of sub-optimality of PSO. Real-coded genetic algorithm (RCGA) with arithmetic average-bound-blend crossover and wavelet mutation is applied to design the digital infinite impulse response (IIR) filter [9]. In this RCGA is applied to obtained stable IIR filter with minimizing Lp-norm approximation error and ripple magnitude. The defined filter offered fast convergence speed and magnitude response nearly to the desired response. The modified PSO based filter design is done in (14) in which the results are compared with GA and the resulting filter is used for the audio processing. So number of new evolutionary techniques has been used since. In this paper I proposed the optimum design of FIR filter using new Hybrid technique which is the combination of PSO and GSA.

II. PSOGSA ALGORITHM

The hybrid PSOGSA was proposed by Seyedali Mirjalili [12] which combines the features of PSO and GSA. The main idea is to integrate the exploration and exploitation feature of GSA and PSO. This algorithm possesses a better capability to escape from local maxima and gives faster convergence rate than the standard PSO and GSA. Before discuss the methodology of PSOGSA we go through the brief description of PSO and GSA.

A. The Standard Particle Swarm Optimization

PSO is proposed by Kennedy and Eberhart [10] in 1995. It was inspired from social behavior of bird flocking. It uses a number of particles which fly around in the search space to find best solution. In the mean time, they all look at the best particle (best solution) in their paths. We can say that particles consider their own best solutions as well as the best solution has found so far. Each particle tries to modify its position using the following information:

• The distance between the current position and the pbest.
• The distance between the current position and the gbest.

Mathematically PSO is expressed as follow [10].

v_i^{t+1} = w $* v_i^t$ + C_1 * rand * ($pbest_i$ $-y_i^t$) + C_2 * rand * (gbest $-y_i^t$) (1)

Where v_i^t is the velocity of particle i at iteration t, w is a weighting function, Cj is a weighting factor, rand is a random number between 0 and 1, y_i^t is the current position of particle i at iteration t, $pbest_i$ is the pbest of agent i at iteration t, and gbest is the best solution so far.

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

$Y_i^{t+1} = y_i^t + v_i^{t+1}$ (2)

The particle position will change continually until the end criteria meet.

B. Standard Gravitational Search Algorithm

GSA has been proposed by E. Rashedi et al in 2009[11]. It is based on Newton's law of universal gravitation and mass interactions. Newton’s Law states that, every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. GSA can be considered as a collection of objects whose have masses proportional to their value of fitness function. During progress, all masses attract each other by the gravity forces between them. A heavier mass has the bigger attraction force. So the heavier masses are nearly close to the global optimum attracts the other masses proportional to their distances. The heavy masses, represents a good solutions, and hence move more slowly than lighter ones, this results the exploitation of the algorithm. The GSA is modeled as follow, suppose we have N agents in a system. The algorithm starts with randomly adjusting all the agents in the search space. At the time t a force acts on mass of agent i from mass of agent j. This force is defined as follows [11]

F_{ij}^d(t) = G (t) $\frac{Mpi\,(t)*Maj\,(t)}{Rij\,+\epsilon}$($Y_j^d$(t) - Y_i^d(t)) (3)

Here $Mpi(t)$ is the passive gravitational mass attain by agent i, $Maj(t)$ is the active gravitational mass attain by agent j, G(t) is the gravitational constant at time t, Rij is the Euclidian distance between two agents, ϵ is the small constant and Y_j^d(t) and Y_i^d(t) are the position of the agents j and I at time t. The total force acting on the agent i in a problem space with dimensions d is-

F_i^d(t)$\sum_{j=1,j\neq i}^{N} rand\,j F_{ij}^d$(t) (4)

According to Newton Law of motion the force acting on a body is equal to the product of mass of the body and acceleration produced in it. So from this acceleration is modeled as-

αcc_i^d (t) = $\frac{F_i^d\,(t)}{Mii\,(t)}$ (5)

Here Mi is the mass of the agent i

The Gravitational constant can be calculated with following equation as in [12]-

G (t) = Go * exp (α * iter /maxiter) (6)

The velocity and the position of agents is calculated as-

v_i^d(t+1) = $rand_i$ * $v_i^d(t)$ + α_i^d(t) (7)

y_i^d(t+1) = y_i^d(t) + v_i^d(t+1) (8)

The different values of Force, acceleration and Mass are calculated using above equation. And after meeting the stopping criteria the GSA will be stopped.

III. HYBRID PSOGSA

The PSOGSA gets the advantages of PSO and GSA. As in it there is a combination of social thinking of PSO and local search capacity of GSA. The combined equation of these two algorithms is as follow in [12]

$V_i(t+1)$ = w * $V_i(t)$ + C1 * rand *$acc_i(t)$ + C2 * rand * (gbest -Y_i(t)) (9)

Here $V_i(t)$ is the velocity of the object i at iteration t, C1 and C2 are the weighting factors, w is the weighting function, $acc_i(t)$ is the acceleration of object i at iteration t and gbest is the best solution at iteration t.

The positions of the agents are updated as follow [12]

Y_i(t+1) = Y_i(t) + $V_i(t+1)$ (10)

In PSOGSA, all agents are randomly initialized. Each agent is considered as a candidate solution. After GSO will operate and different notations like force, gravitational constant and resultant force is calculated using above equations. After that acceleration is calculated using equation (5) and the best solution so far is updated. After this velocity and final position of all the agents in a system is calculated using equation (7) and (8). After meeting an end criterion the updating of velocity and positions of the agents will be stopped.

Following are steps of the PSOGSA

- Initialize the particles randomly in the problem search space.
- Calculate the fitness function for each agent.

- Update the values of gravitational constant and gbest for the whole population.
- Calculate others values like Force Mass and acceleration for all the particles.
- Update velocity and position of each particle.
- Check the stopping criteria, repeat the steps 2 to 5 until the stopping criteria is met.

IV. PROBLEM FORMULATION

The digital filter is mathematically represented as-
H(z) = $\sum_{n=0}^{N} h(n)\, z^{-n}$, n = 0,1,2..N (11)
Here h(n) is impulse response of the filter, N is the order of the filter which has N+1 coefficients. Basically there are four type of filter based on symmetric and anti symmetric and on odd and even value of impulse response. In evolutionary algorithm the there is tendency to attain the actual filter response as close to ideal filter response. In this paper PSOGSA algorithm is used for the design of FIR LP filter and result is compared with GA and MPSO. So the fitness function for PSOGSA is the error function between actual filter response and the ideal filter response. In this paper fitness function is the squared difference between the magnitude response of ideal filter and the magnitude response of actual filter and is given by
Fitness function = $\frac{1}{N} \sum_{n=1}^{N}(\ |Hideal|-|Hobtained|)^2$ (12)

V. SIMULATION RESULTS

The simulation has been performed on Matlab for FIR Low Pass filter having order 20 with filters coefficients length 21. The filter specifications are given in table-

Table 1: Filter design specifications

Filter Specifications	Values
Passband frequency	0,.5Л
Stoopband frequency	.6 Л,1
Cut-off frequency	1.7279
Order	20

Table2: PSOGSA specification

Specifications	Values
Population size	30
C1	0.5
C2	1.5
Random number	[0,1]
Maximum iterations	200

The simulation results for the design of FIR LP filter of order 20 with PSOGSA is shown in figure 1. The results shows that the low pass filter designing with PSOGSA shows fast convergence less ripple factors in pass band and less attenuation in the stop band. The filter has sharper transition response than GA and PSO. The filter coefficients are given in table 3 and are compared with GA and MPSO. With the help of PSOGSA the filter coefficients are optimized to greater extent as compared to GA and MPSO.

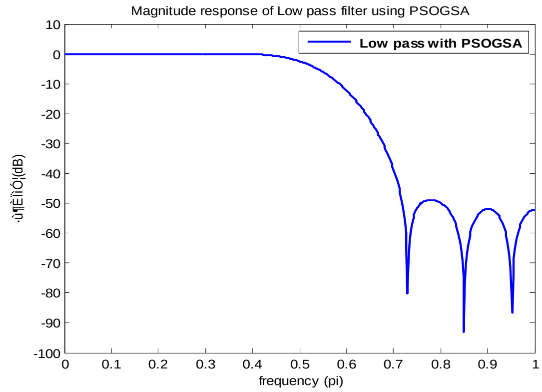

Figure 1: Magnitude response of FIR LP filter using PSOGSA

Table 3: Optimised coefficients of FIR Low pass filter

h(n)	**GA**	**MPSO**	**PSOGSA**
h(1) = h(21)	0.0174	0.4492	-0.0075
h(2) = h(20)	0.0085	0.0781	0.0017
h(3) = h(19)	-0.0164	-0.5340	0.0187
h(4) = h(18)	0.0157	-0.2913	-0.0164
h(5) = h(17)	0.0248	0.6056	-0.0502
h(6) = h(16)	0.0101	0.6352	0.0714
h(7) = h(15)	-0.0533	-0.6600	0.0938
h(8) = h(14)	-0.0632	-1.3340	-0.2251
h(9) = h(13)	0.0703	0.6940	-0.1318
h(10) = h(12)	0.2751	4.4364	0.9031
h(11)	0.3982	6.3500	1.6163

Table 4 Other results using PSOGSA

Maximum passband ripple	**Maximum stopband attenuation**
2.3650	12

VI. CONCLUSION

The FIR low pass filter design using new hybrid PSOGSA algorithm has been discussed in this paper. The result shows that the design of filter using PSOGSA has optimised filter coefficients, to greater extent as compared to GA and MPSO. Also the rate of convergence of PSOGSA is faster than both others algorithms within very small number of iterations and much less execution time.

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