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COMPARISON OF VARIOUS FIR LOWPASS FILTER DESIGN TECHNIQUES WITH PSO ALGOTIRHM

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ABSTRACT :This paper presents an optimization technique for the design of optimal digital FIR low pass filter. The design of digital FIR Filters possible by solving a system of linear equations .In this paper we are using PSO (particle Swarm Optimization).PSO method is used to determine the frequency response of Digital FIR filters, consequently the optimal filter coefficients are obtained with fast convergence speed. PSO technique is purely random algorithm. PSO technique provides optimal filter coefficients such that error function is minimized when compared with the traditional FIR filter design techniques such as windowing techniques. The convergence speed of PSO is faster than the traditional FIR filter design techniques. Particle Swarm Optimization technique which has been applied in many areas such as function optimization, fuzzy system method and other areas.

Key words: PSO, gbest, pbest, FIR, weighting factors

I. INTRODUCTION

Particle Swarm Optimization is a population based stochastic optimization technique developed by Dr.Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling. In PSO the potential solutions, called particles, fly through the problem space by following the current optimum particles. Each particle keeps track of its Coordinates in the problem space which is associated with best solutions (fitness) it has achieved so far. This value is called pbest. When a particle takes all the population as its topological neighbors. The best value is called towards its gbest location. global best (gbest). The particle swarm optimization concepts consist of, at each time step, changing the velocity of each particle Section I gives the introduction of PSO algorithm. Section II explains the problem formation and mathematical background of PSO.

Section III explains the proposed PSO algorithm. Section IV shows the performance of the proposed technique and section V concludes the paper and followed by the references.

II. PROBLEM FORMULATION AND MATHEMATICAL BACKGROUND OF PSO

The frequency response of a linear-phase FIR filter is given by ref(5)

$H(e^{jw})=\sum_{i=0}^{N} h(n)e^{-jwn}$ ref(5) (1)

Where h(n) is the real valued impulse response of filter, N+1 is the length of filter and ω is frequency according to the length being even and odd and the symmetry being an even and odd four types of FIR filters described. The linear phase is possible if the impulse response h(n) is either symmetric(h(n) =h(N-n)) or is anti symmetry (h(n)=-h(N-n)) for $0\leq n \leq N$ In general the frequency response for type1 FIR filter can be expressed in the form

$$H(e^{j\omega}) = e^{-jn\omega/2}\tilde{H} \text{ ref(5)} \qquad (2)$$

Where amplitude response $\tilde{H}(\omega)$, also called the zero response, is given by

$$\tilde{H}(\omega) = h(N/2) + \sum_{n=1}^{N/2} h(N/2-n)\cos(\omega n) \qquad (3)$$

the amplitude response for the type 1 linear phase FIR filter (using the notation N=2M) is expressed as

$$\tilde{H} = \sum_{k=0}^{M} a(k)\cos(\omega k) \text{ ref(5) (4)}$$

Where a(0)=h(M) and a(k) = 2h(M-k), 1<=k<M

The amplitude response for the type 2 linear phase FIR filter is given by

$$A(\omega) = \sum_{i=1}^{k}\{W(\omega_i)[\sum_{k=0}^{M} a(k)\cos(\omega_i k) - D(\omega_i)]\}\wedge 2$$

$$\partial \in / \partial a(k) = 0$$

$$(5) \qquad A(\omega) = \sum_{k=1}^{2M+1/2} b(k)\cos[\omega(k-1/2)$$

Where b(k)=2h[2m+1/2-K], 1<K<2M+1/2.

The amplitude response for the case of type 3 linear phase FIR filter is given as

$$A(\omega) = \sum_{k=1}^{M} c(k)\sin(\omega k)$$

Where c (k) = 2h (M-k) 1<=k<=M

The amplitude response for the case of type 4 linear phase FIR filter is given as

$$H(\omega) = \sum_{k=1}^{2M+1/2} d(k)\sin[\omega(k-1/2)$$

Where d(k)=2h[2M+1/2-k] 1<=k<=2M+1/2

The design of a linear phase FIR filter with least mean square error criterion, we find the filter coefficients a(k) such that error is minimized. Corresponding to the coefficients the filter coefficients are obtained as shown by the equations.

The Least mean square design function for this design is given as

Є= $\sum_{i=1}^{k} W(\omega_i)[A(\omega_i - D(\omega_i)]$ ref(5)

for type 1 FIR filter the amplitude response A(w) is a function of a(k) to arrive at the minimum value of ϵ , we set

$\partial \in / \partial a(k) = 0$ 0<=k<=M

Which results in a set of (M+1) linear equations that can be solved for a(k)

For the type 1 the expression for mean square error is ε expressed as

$$\sum_{i=1}^{k} \{W(\omega_i)[\sum_{k=0}^{M} a(k)\cos(\omega_i k) - D(\omega_i)]\}\wedge 2 \quad (6)$$

A similar formation can be derived for the other three types of linear phase FIR filters. This Design approach can be used to design a linear phase FIR filter with arbitrarily shaped desired response. Where D(w)is the frequency response.

III. PROPOSED PSO ALGORITHM

Particle Swarm Optimization (PSO) algorithm is a population based optimization algorithm. Its population is called a swarm and each individual is called a particle. Each particle flies through the solution space to search for global optimization solution. The implementation of PSO algorithm for optimizing the filter coefficients is given as follows. ref (3).

Step 1:
Error function is to be minimized is expressed in equation

Step 2:
Initial population (swarm) is generated where each particle in the swarm is a solution vector containing M=5 elements, then initial population can be expressed as

$$U_i^0 = [U_{i1}^0, U_{i2}^0, U_{i3}^0, U_{i4}^0, U_{i5}^0]$$

Particle U_{ij}^0 of particle U_j^0 is generated from uniform distribution [0 , $U_{ij,\max}^0$].

Step 3:
Initial velocities of each particle are written as follows

$V_i^0 = [V_{i1}^0, V_{i2}^0, V_{i3}^0, V_{i4}^0, V_{i5}^0]$ i=1, 2 ,.....5

Each elements V_{ij}^0 of V_j^0 is selected a random digits for example, between
[0, 0.1 $x_{i,\max}$]

Step 4:
Set iteration count K=1.

Step 5:
Calculate Error value by using eq (6).

$$\in = \min[\in_1, \in_{2,} \in_{3,} \in_{4,} \in_5]$$

And corresponding particle is the gbest is the particle which leads to Є.

Step 6: Update velocities of each particle using following relation

Where $Pbest_i^k$ is the best previous position of the i th particles, $gbest^{k-1}$ is particle which leads to ε

$$V_i^k = W * V_i^{k-1} + c1 * r1(pbest_i^{k-1} - U_i^{k-1})$$
$$+ c2 * r2(gbest_i^{k-1} - U_i^{k-1})$$

the position among all partilcles.r1 and r2 are random digits between [0,1].c1 and c2are acceleration constants and W an inertia weight typically selected in the range 0.1 to 2.ref(1)

Step 7:
Update position of each individual particle as

$$U_i^k = U_i^{k-1} + V_i^k$$

Where i=1, 2....M.

Step 8:
Update $Pbest_i^k$ and $Gbest_k$

$$U_i^k = U_i^{k-1} + V_i^k$$

$Pbest_i^k$ = U_i^k

if C(U_i^k)<C($Pbest_i^k$)

= $Pbest_i^k$

if C (U_i^k)>=C($Pbest_i^k$)

Out of all particles which give min error gives the Gbest.

Step 9:

Repeat 5 to 9 for maximum no of times to get the least possible error.

IV. SIMULATION RESULTS

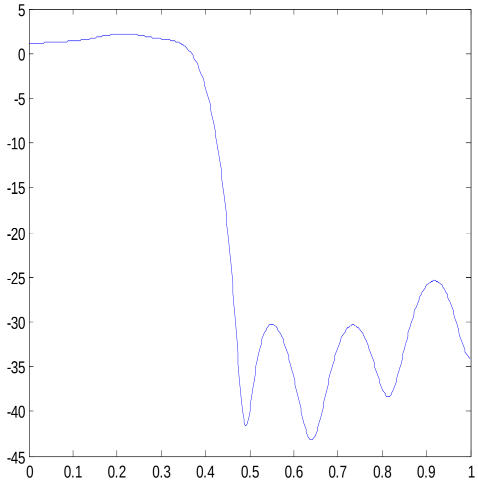

Fig 1. Frequency response of first order low pass FIR digital filter (frequency vs gain(db))

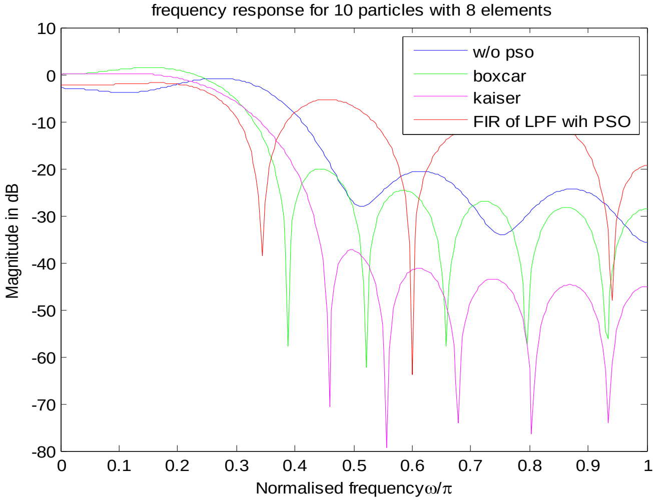

Fig 2. Comparison of Fir low-pass filter response using PSO with Rectangular, Kaiser and Hamming windowing techniques.

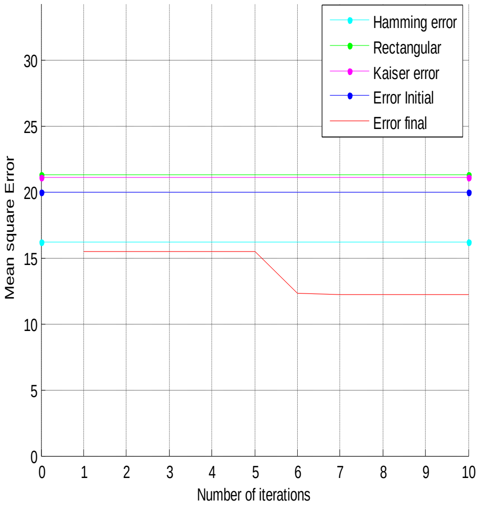

Fig 3. Error plot

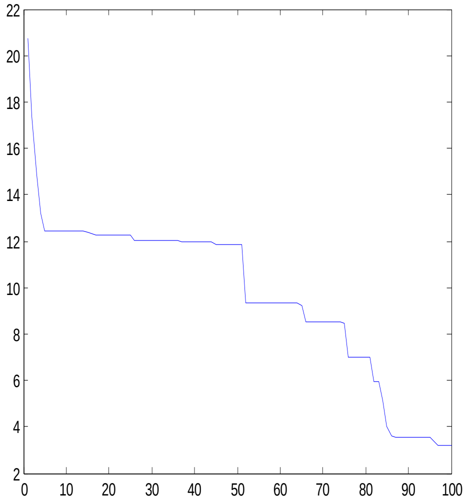

Fig 4. No of Iterations (N=100) VS MSE

Frequency response of FIR lowpass filter with PSO algorithm attains the ideal frequency response compared with without PSO algorithm that is the mean square error is minimum for PSO algorithm compared to the without PSO.

V. CONCLUSIONS

The information mechanism in PSO is significantly different. So the whole population moves like a one group towards an optimal area. In PSO, only gbest gives out the information to others. PSO converges to the best solution quickly and gives min error. The frequency response of PSO is better than rectangular, Kaiser and hamming windowing techniques, as the no iterations increases error is reduced. How ever PSO does not have any genetic operators like crossover and mutation. So PSO is better than traditional windowing techniques such as rectangular, Kaiser and hamming windowing techniques.

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Biography

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