

# FIR DIGITAL FILTER WITH VARIOUS OPTIMIZATION TECHNIQUES

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**Abstract :** The main purpose of the filters is to allow some frequencies to pass unaltered, while completely blocking others. Some frequencies are passed through the filter and some frequencies are blocked by filter. The use of different optimization technique, such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), has been proved to be quite useful towards the design of those digital filters with certain specifications. This paper describes different optimization methods of FIR filtering. The efforts are made so as to have reduced computational effort, hardware cost and better optimization results.

**IndexTerms – FIR, Particle swarm optimization (PSO), Real Genetic algorithm (GA), Steepest descent optimization algorithm, Differential evolution algorithm (DE)**

## I. INTRODUCTION

Digital signal processing (DSP) is one of the leading fields in modern electronics. It is being used in all areas where information is handled in digital form or controlled by digital processor. Nowadays, most efficient and powerful DSP processors are available for various DSP tasks such as digital filtering, linear convolution, circular convolution etc. We need to design pulse shaping filters with some constraints imposed by requirements of the communication system in which we are going to use them. The use of different optimization technique, such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), has been proved to be quite useful towards the design of those digital filters with certain specifications. These techniques give better control on parameters as well as better approximate the ideal filter. Differential evolution [6], Genetic algorithm [7] and Artificial intelligence algorithms are some intelligent optimization techniques, which provide better facility of designing digital filters. The designing methods of FIR filters are well established in all DSP books and filter design software packages.

Filters are frequently used in signal processing by virtue of easy implementation and stability. In signal processing, the function of filters is to remove unwanted parts of the signals, such as random noise, or to extract useful parts of the signal, such as the components lying within a certain frequency range [1]. There are mainly two kinds of filters, analog filter and digital filter. Digital filtering is one of most important tool of DSP. Digital filtering are capable of performing that specification that are extremely difficult, to achieve with analog implementation [2, 3]. The characteristics of digital filtering can also be easily changed under software control. Two types of filtering provide these functions finite impulse response (FIR) and infinite impulse response (IIR).

An FIR filter has a number of useful properties which sometimes make it preferable to an infinite impulse response (IIR) filter. The advantages of FIR filter over IIR filter are given below [13][15][16][17][18][14]:

1. FIR filters are stable.
2. FIR filters can be easily designed as for its linear phase.
3. FIR filters, when implemented on a finite word length digital system, are free of limit cycle oscillations.
4. There are various methods are available for designing the FIR filter.
5. FIR filter require no feedback i.e., any rounding error are not compounded by summed iteration and for that it is inherently stable.
6. Impulse response is finite.

Lot of researchers have used many heuristic and meta-heuristic evolutionary optimization methods in which the majority are related to the evolutionary and natural techniques. These include Genetic algorithm (GA) [4], Differential algorithm (DE) [5, 6], Simulated annealing algorithm [7, 8], Bee colony optimization [9], artificial neural networks [10], and Collective animal behaviour (CAB) [11]. With the availability of the gradient and hessian of the objective function in closed form, enable us to develop an optimization method for the design of FIR filter. The Parks-McClellan algorithm and its variant have been most efficient tools for the minimax design of FIR digital filters [19]. However, these algorithms apply only to the class of linear-phase FIR filters the group delay introduce by these filters is independent of frequency in the entire baseband but it can be quite large.

## II. OPTIMIZATION METHODS

### 2.1 Particle Swarm Optimization

The Particle Swarm Optimization (PSO) [21] is a population based intelligent optimization technique that is effective in multidimensional nonlinear environment. It is developed from swarm intelligence and inspired by social behaviour of birds flocking and fish schooling. It is based on the natural process in which swarms of particles share their individual knowledge. PSO

algorithm uses a number of particle vectors moving around for finding optimal solution in search space. The solution is obtained according to personal experience of each particle vector. Many authors have worked on PSO based FIR filter designing, the study of the simple model of the bird and the behaviour of the bird and its simulation. Similar steps for PSO as [20] are implemented for the optimization of filter coefficients  $h(n)$ :

Step1: Initialization: population of particle vectors  $n_p = 50$ ; maximum iteration cycle=500; filter order= $nvar=20$ ;(nvar/2+1)

number of coefficients  $h(n)$ .

Step 2: Generation of initial particle vectors

of filter coefficients (nvar/2+1) randomly with limits.

Step 3: Computation of the initial personal best

solution vectors ( $p\_best$ ) and the group best solution ( $g\_best$ ).

Step 4: Updating the velocities and particle vectors by the

following equations:

$$V_i^{(k+1)} = w * V_i^k + C_1 * rand_1 * (p\_best_i^k - S_i^k) + C_2 * rand_2 * (g\_best^k - S_i^k)$$

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

Step5: Updating of the  $g\_best$  and  $p\_best$  on the basis of the fitness values.

Step6:

Iteration continues from step 4 till the maximum number of cycles is reached.

Step7: Finally,  $hg\_best$  is

the vector of the optimal filter coefficients (nvar/2+1). Now copying and concatenating the complete nvar coefficients in order to obtain the optimal frequency response.

PSO approach is flexible, robust and population based stochastic

search and can easily be handled with non –differential objective functions of digital filters. This is the best method of the

optimization. By applying PSO to optimize transition sample values, the maximum stop band attenuation in FIR filter is obtained

## 2.2 Real coded Genetic Algorithm

Genetic algorithm is an optimization method which resembles the natural selection. A set of vectors which can act as a potential solution of the problem at hand is called genome (chromosome). A set of genomes is called population. GA creates new generations by applying some genetic operators to the individuals of population. Investigation into increasing this integration by using a binary coded GA to optimize nonlinear phase, quantized coefficient FIR filter are introduced, with an analysis of the difficulty of the problem from a GA perspective [23].

In RGA, firstly initialize the real chromosomes string vectors of  $n_p$  population. Each vector string consists of (n/2+1) numbers of  $h(n)$  coefficients for Nth order FIR filter design. The steps of RGA as adopted from [24, 25] and are used for the implementation process as under:

Step 1: Firstly initialize the vector string (within bounds -2 and +2).

Step 2: Evaluation of the error fitness of each string vector. (H):  $Fitness = 1/abs(\varepsilon(\omega))$

Step 3: Make the selection of sting so that it increases the error fitness value from the minimum value.

Step 4: Now copying the strings over the strings which are not selected.

Step 5: Crossover and mutation generate the off-spring.

Step 6: Genetic cycle updating and iteration repeats from step 2.

The iteration process stops when the maximum number of iteration cycles reached. The minimum error fitness, optimal filter coefficients and (n+1) number of filter coefficients are finally obtained by copying and concatenating the filter coefficients in order to get the final optimal frequency spectrum of the FIR filter.

## 2.3 Steepest descent optimization algorithm

The steepest descent optimization algorithm was proposed by Joaquim and Lucietto in 2011 [17, 18]. It minimizes the mean square error between the desired frequency response and the frequency response of the approximation. The advantage of this algorithm is that there is no need to select the filter order in advance. In case any error occurs the algorithm increases the filter order. Given the desired frequency response,  $H_d(e^{j\omega})$  and a maximum approximation error  $\delta$ , the proposed algorithm for the steepest-descent method adjust the weights  $h(n)$  is

Step 1: Initialization: guess an estimate for M where it defines the filter coefficient and  $h(n)$ ;

Step 2: Choose the step size  $\mu$  where the maximum value of size  $\mu$  is  $\mu \leq 2/1+2M$

Step 3: Search the maximum absolute error in frequency band;

Step 4: If absolute

error /  $\varepsilon^{i+1}(w_k)$  / is less than  $\delta$ , stop the approximation.

Step 5: If error is not less than  $\delta$ ,

increase M by one, i.e, set a new column which has zero value in the last estimate of  $h(n)$  and go to step 3;

Step 6: Else if the error is more than  $\delta$ , calculate the new filter coefficient using the equation

$$h^{i+1}(n) = h^i(n) - \mu \in (w_k) \cos(w_k n)$$

Where  $n = 0, 1, 2, \dots, M,$

Step 7: Go to step3.

The algorithm is very simple, produces acceptable digital FIR filters, presents less errors and can easily be implemented on digital computers.

**2.4 Differential evolution algorithm**

Storn and Price in 1995 first introduced the DE algorithm [26, 27]. The main idea behind this algorithm is a method for generating trial parameter vectors and adds the weighted difference between two population vectors to a third one. The performance of DE optimization technique has been evaluated in terms of its convergence behaviour for different mutation schemes in [28]. As every other algorithm objective is to evolving a population of  $n_p$ , D- dimensional parameter vectors so called individuals, that helps in encoding the candidate solution, i.e.,

$$x_i, g = \{x_{1,1,g}, x_{2,1,g}, x_{3,1,g}, \dots, x_{D,1,g}\}$$

Where  $i = 1, 2, 3, \dots, n_p$ .

Following step are performed for the implementation of DE algorithm:

Step 1: Firstly initialization of all the individual of  $n_p$  population takes places randomly every population consists of  $(N/2+1)$  number of  $h(n)$  coefficients.

Step 2: Mutation: for  $i=1$  to  $n_p$ , generate a mutated vector,  $v_{i,g} = \{v_{i,g}, v_{2,g} \dots v_{d,g}\}$  corresponding to the target vectors  $x_{i,g}$ , the best value of F determined in this work equals to 0.5.

Step 3: Crossover: Generate a trial vector  $u_{i,g}$  for each target vector  $x_{i,g}$  where  $u_{i,g} = \{u_{1,g}, u_{2,g} \dots u_{d,g}\}$ .

Step 4: Selection.

Step 5: Increment the generation count  $g=g+1$ . The generation cycle repeats from step 2 till the maximum number of generation cycle is reached.

This algorithm is most reliable and effective is order to get the optimal linear response of FIR filter. Hence the power dissipation can also be eliminated. It has been observed that the DE algorithm based on reverse gene can also be applied for the design of digital filter [29]. It can produce new chromosomes in every generation by combining reversed gene of special chromosome into a single entity. The performance of DE is comparable to that of GA since the local search ability of DE is better than that of GA.

Table1 shows the survey of various optimization techniques.

Sr. No.	Paper Title	Techniques Followed	Results
1.	Linear phase FIR filter design using particle swarm optimization and genetic algorithms	PSO and GA	PSO gives better results for both finite and infinite word length.
2.	Differential Evolution Particle Swarm Optimization for Digital filter design	PSO and DEPSO	DEPSO gave the better results as it prevents the particles to get trapped in local minima.
3.	A hybrid genetic algorithm for the design of FIR filters with SPoT coefficients	GA, Hybrid GA, Simulated Annealing, Adaptive GA	Hybrid Genetic Algorithm proved as better results as it normalizes the peak ripples of the filter.

### III. CONCLUSION

On surveying the various papers, it can be concluded that the Differential Evolution Particle Swarm Optimization (DEPSO), Genetic Algorithm (GA), Hybrid Genetic Algorithm (GST) have proved to be better optimization techniques. The analysis is carried out using the filter parameters like passband and stop band frequencies, cut off frequency; ripple size, attenuation factor and Weighting factor. The efforts are made so as to have the reduced computational efforts and hardware cost. Many authors have proposed different variants of PSO and proved PSO to be a very efficient, reliable and evolutionary design technique for FIR filter design.

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