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Design of Optimum Digital FIR Low Pass Filter Using Hybrid of GA & PSO Optimization

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Abstract-Digital filters have found important applications in an increasing number of fields in science and engineering, and design techniques have been developed to achieve desired filter characteristics. 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, design techniques of low pass FIR filters using Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and Hybrid system of GA and PSO are presented. The magnitude response and filter coefficients are demonstrated for different optimization techniques. Comparison the various optimization techniques has been done the hybrid optimization performs better in comparisons to genetic algorithm and particle swarm optimization. This in turn improves design efficiency as well as the algorithm's numerical stability which is of critical importance for the design filter. Design examples with comparisons are presented to illustrate the effectiveness of the hybrid optimization method.

Keywords: Digital filters, FIR filter, GA, Hybrid, Low Pass Filter, PSO.

I. Introduction

Digital filter is essentially a system or network that improves the quality of a signal and/or extracts information from the signals or separates two or more signals which are previously combined. Digital filters are used in numerous applications e.g. control system, system for audio and video processing and communication systems. Now a day's digital filters can be used to perform many filtering tasks are replacing the traditional role of analog filters in many applications. Digital filters can be applied to very low frequency signals, such as those occurring in biomedical and seismic applications very efficiently. In addition, the characteristics of digital filters can be changed or a adapted by simply changing the content of a finite number of registers, thus multiple filters are usually used to discriminate a frequency or a band of frequencies from a given signals which is normally a mixture of both desired and undesired signals. These are mainly two types of filter algorithms. They are finite impulse response filter (FIR) and infinite impulse response filter (IIR). In case of a FIR filter, the response due to an impulse input will decay with in a finite time. But for IIR filter, the impulse response never dies out. FIR filters are commonly known as non-recursive filters and IIR filters are known as recursive filters. These names came from the nature of algorithm used for these filters [1]. A finite impulse response (FIR) digital filter is one whose impulse response is of finite duration. The impulse response is 'finite' because there is no feedback in the filter if put in an impulse (that is, a single "1" sample followed by many "0" samples), zeroes will eventually come out after the "1" sample has made its way in the delay line past the entire coefficient. The structure of these algorithms uses a repetitive delay-and-add format that can be represented as "Direct Form-I Structure" [2]. The advantage of FIR filter over IIR filters are, FIR filter has linear phase and easily to control where as IIR filter has no particular phase and difficult to control. FIR filter is stable and depends only on input. FIR filters consists of only zeroes and IIR filters consists of both poles and zeroes. FIR filters are filters having a transfer function of a polynomial in z-plane and is an all-zero filter in the sense that the zeros in the z-plane determine the frequency response magnitude characteristics. The z transform of N-point FIR filter is given by:

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

Where N is the order of the filter which has (N+1) number of coefficients. h(n) is the filter's impulse response. It is calculated by applying an impulse signal at the input. The values of h(n) will determine the type of the filter e.g. low pass, high pass, band pass etc. the values of h(n) are to be determine in the design process and N represents the order of the polynomial function [1]. FIR filters are particularly useful for applications where exact linear phase response is required. The FIR filter is generally implemented in a non-recursive way which guarantees a stable filter.

FIR filter design essentially consists of two parts:

i. Approximation problem
ii. Realization problem

The approximation stage takes the specification and gives a transfer function through four steps. They are as follows:

i. A desired or ideal response is chosen, usually in the frequency domain.
ii. An allowed class of filters is chosen.
iii. A measure of the quality of approximation is chosen.
iv. A method or algorithm is selected to find the best filter transfer function.

The realization part deals with choosing the structure to implement the transfer function which may be in the form of circuit diagram or in the form of a program [3].

In case of a FIR filter, it is an attractive choice because of the ease in design and stability. By designing the filter taps to be symmetrical about the centre tap position, the FIR filter can be guaranteed to have linear phase. Finite impulse response (FIR) digital filters are known to have many desirable features such as guaranteed stability, the possibility of exact linear phase characteristic at all frequencies and digital implementation as non-recursive structure. Linear phase FIR filter are also required when time domain specifications are given. Traditionally, different technique exit for the design of digital filters [1].

II. Methodology

Optimal digital FIR low pass filter is designed using different optimization techniques. For this purpose, three main optimization techniques are used. These optimization techniques are Genetic algorithm (GA), Particular swarm optimization (PSO), hybrid (GA & PSO) optimization [7].

2.1 Optimization techniques:

Optimization is the act of obtaining the best results under given circumstances. Optimization can be defined as the process of finding the condition that gives the maximum or minimum value of the function. If x* corresponds the minimum value of function f(x), the same point also corresponds to maximum value of the function –f(x). Thus optimization can be taken to mean minimization since the maximum of the function can be found by seeking of the negative of the same number [3]. According to proposed work, two optimization techniques GA & PSO used for design optimum digital FIR filter using HYBRID of GA & PSO.

2.1.1 Genetic Algorithm

A Genetic algorithm (GA) is an optimization technique that is based on the evolution theory. Instead of searching for a solution to a problem in the "state space" (like the traditional search algorithms do), a GA works in the "solution space" and builds new, hopefully better solution based on existing ones. GA operates with a collection of chromosomes, called a population. The population is normally randomly initialized. The population includes fitter and fitter solution, and eventually it converges, meaning that it is dominated by a single solution. The general idea behind GA is that it build a better solution if somehow combine the "good" parts of other solutions (schemata theory), just like nature does by combining the DNA of living beings [4].In GA, different operators to generate new solutions from existing ones. These operators are based on reproductions, reproduction operators are crossover and mutation. The size of each chromosome must remain the same for crossover to be applied. Fittest chromosomes are selected in each generation to produce offspring which replace the previous generation. The good individuals remain in the population and reproduce; while the bad individuals are eliminated from the population finally the population will consists only of the best individuals fulfilling the design specifications. The genetic algorithm is an artificial genetic system based on the process of natural selection and genetic operators. Genetic algorithm is a heuristic algorithm which tries to find the optimal results by decreasing the value of the objective function.

Crossover: The crossover operator is the most important operator of GA. In crossover, generally two chromosomes, called parents, are combined together to form new chromosomes, called offspring. The parents are selected among existing chromosomes in the population with preference towards fitness so that offspring is expected to inherit good genes which make the parents fitter [2][7].

Mutation: The mutation operator introduces random changes in to characteristic of chromosomes. Mutation is generally applied at the gene level. There is a chance that a gene of a child is changed randomly. Generally the chances of mutation are low. Therefore, the new chromosome produced by mutation will not be very different from the original one. Mutation is a unary operator that is usually applied with a low probability [6].

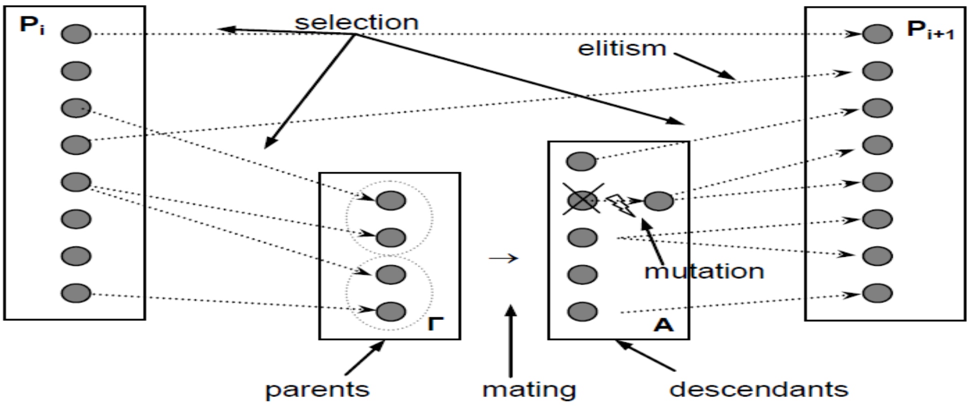

Figure 1: Outline of Genetic Algorithm

Reproduction involves selection of chromosomes for the next generation.

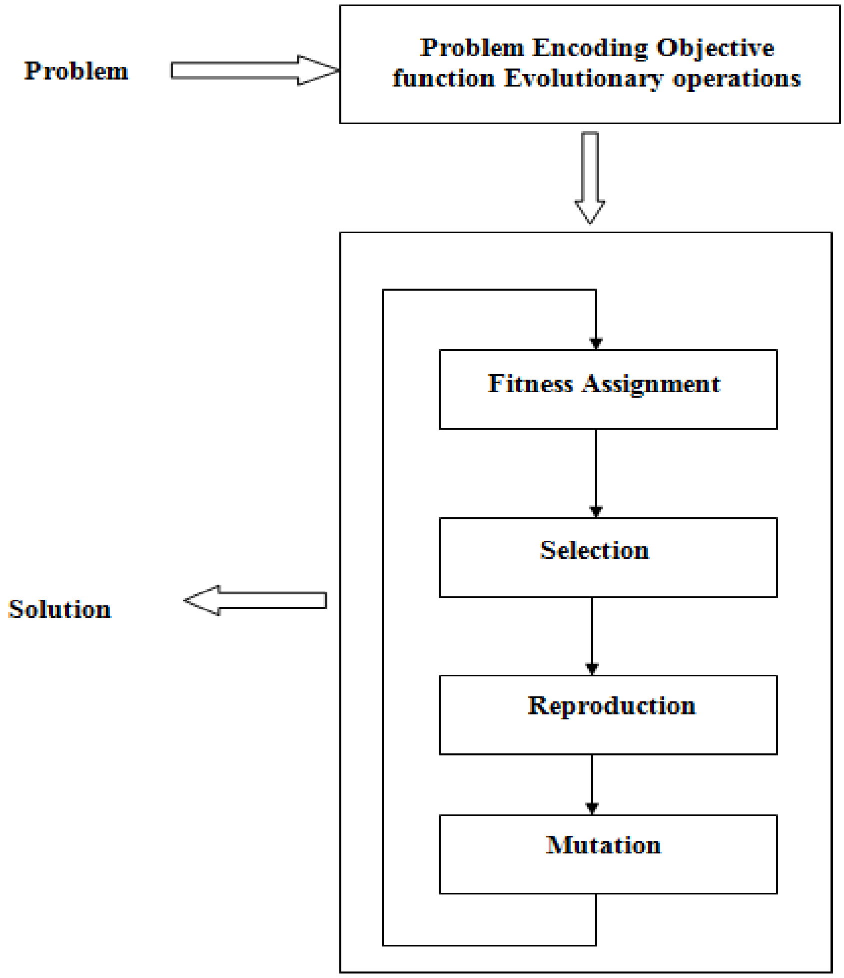

Figure 2: Flowchart of GA

Objective Function: The purpose of the optimization is to choose the best one of many acceptable designs available. Thus a criterion has to be chosen for comparing the different alternative acceptable design and for selecting the one. The criterion, with respect to which the design is optimized, when expressed as a function of the design variables, is known as objective function.

Fitness Function: A fitness function is a particular type of objective function that is used to summarize, as a single figure of merit. Fitness function must be devised for each problem to be solved. Given a particular chromosome, the fitness function returns a single numerical "fitness, "figure of merit," which is supposed to be proportional to the "utility" or "ability" of the individual which that chromosome represents.

Selection: This step consists in selecting individuals for reproduction. This selection is done randomly with a probability depending on the relative fitness of the individuals so that best ones are often chosen for reproduction than poor ones [4]-[6].

2.1.2 Particle Swarm Optimization

Particle swarm optimization (PSO) is optimization techniques that can be flexible, robust population-based stochastic search or optimization techniques with implicit parallelism, which can easily handle with non-differential objective function, unlike traditional optimization method. PSO is less susceptible to getting trapped on local optima unlike GA [6]. PSO is a techniques used to explore the search space of a given problem to find the settings or parameters required to maximize a particular objective. The PSO works by simultaneously maintaining several candidate solutions in the search space. During each iteration of the algorithm, each candidate solution is evaluated by the objective function being optimized determine the fitness of that solution. Each candidate solution can be thought of as particle "flying" through the fitness landscape finding the maximum or minimum of the objective function. Particle swarm optimization is a robust stochastic optimization techniques based on the movement and intelligence of swarms. PSO uses a number of agents (particle) that constitute a swarm moving around in the search space looking for the best solution. Each particle is treated as a point in an N-dimensional space which adjusts its "flying" according to its own flying experience as well as the flying experience of other particles [2]. The PSO is easy to apply and its convergence may be managed using a small number of factors. PSO is an elastic, vigorous population-based stochastic search or optimization method with understood parallelism, which can, with no trouble, handle non-differential purpose functions, different customary optimization techniques.

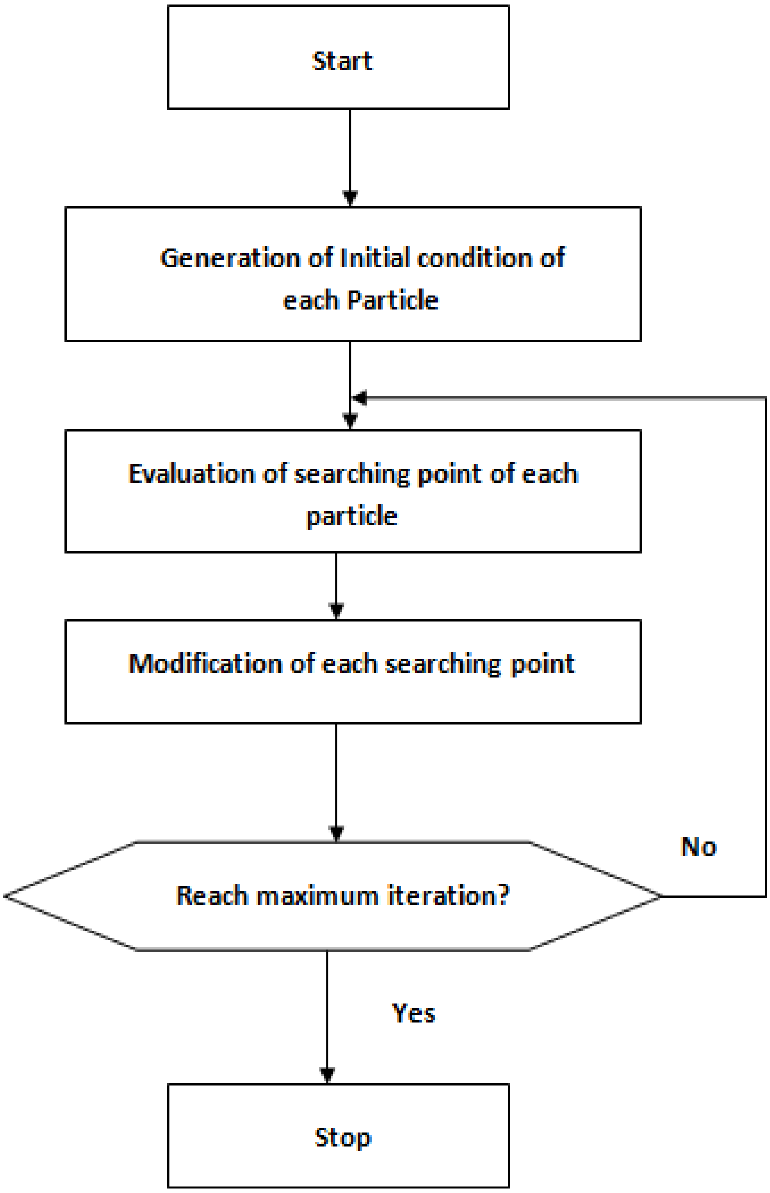

Figure 3: Flowchart of PSO

2.1.3 Hybrid of GA & PSO

Hybrid optimization (HGAPSO) is the proposed work. In this work, digital FIR low pass filter is designed using different optimization techniques. For this purpose, genetic algorithm, particle swarm optimization techniques are used. These optimization techniques are evolutionary techniques. A Genetic Algorithm is an optimization technique that is based on the evolution theory. Instead of searching for a solution to a problem in the "state space" (like the traditional search algorithms do), a Genetic Algorithm works in the "solution space" and builds (or better, "breeds") new, hopefully better solutions based on existing ones. The general idea behind Genetic Algorithm is that build a better solution if somehow the "good" parts of other solutions are combined (schemata theory), just like nature does by combining the DNA of living beings. Particle swarm optimization is a flexible, robust population base stochastic search or optimization techniques with implicit parallelism, which can easily handle with non-differential objective functions, unlike traditional optimization methods. Particle swarm optimization is less susceptible to getting trapped on local optima unlike Genetic algorithm simulated annealing etc. Particle swarm optimization is a robust stochastic optimization technique based on the movement and intelligence of swarms. Particle swarm optimization applies the concept of social interaction to problem solving. Each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best, **pbest** [6]. Another best value that is tracked by the particle swarm optimization is the best value obtained so far by any particle in the neighborhood of that particle. This value is called global best, **gbest**. Particle swarm optimization shares many similarities with evolutionary computation techniques such as Genetic Algorithms. In this work, the proposed work is to design digital FIR low pass filter [7]. A hybrid optimization technique is the combination of both Genetic algorithm and Particle Swarm Optimization techniques. This new evolutionary learning algorithm is based on a hybrid of genetic algorithm and particle swarm optimization, and is thus called Hybrid optimization. In Hybrid optimization, individuals in a new generation are created, not only by crossover and mutation operation as in Genetic algorithm, but also by Particle swarm optimization.

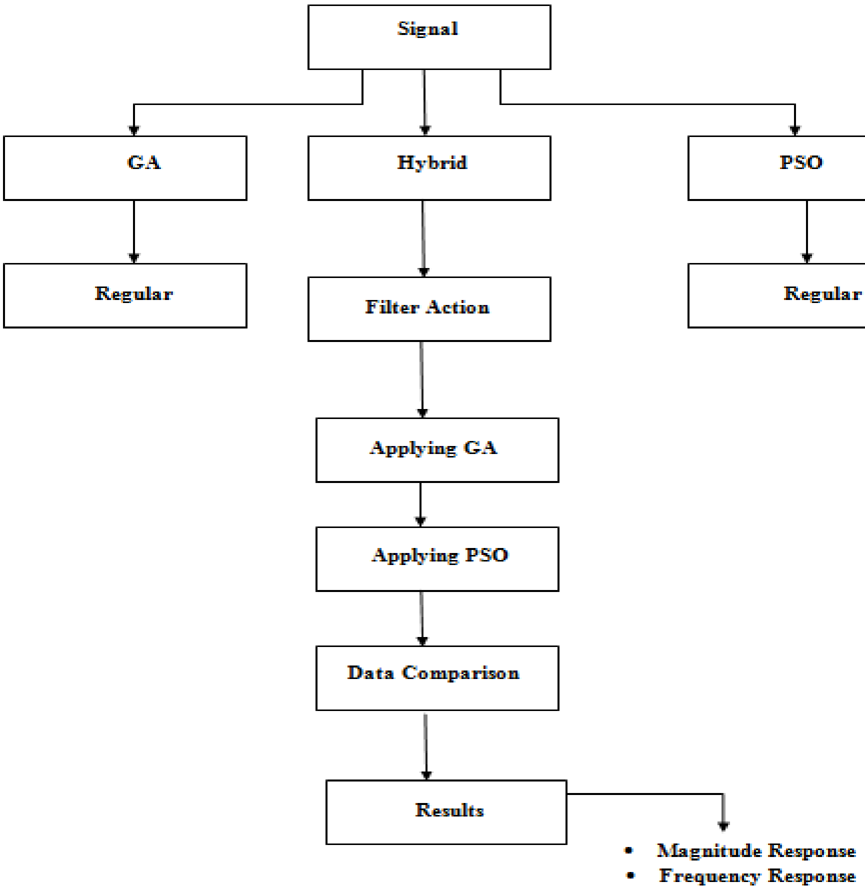

Figure 4: Flowchart of Hybrid

III. Results and Discussion

In this paper, A Digital FIR low pass filter is designed using different optimization techniques. These techniques are GA, PSO and Hybrid (GA & PSO). FIR filter is designed in MATLAB version 7.7.0.471 (R2008b). The parameters for designing digital FIR filter using Optimization are shown in table 1.

Table 1: Select Parameters of Optimized Algorithms for FIR filter

Order (N)	10, 15, 20, 25, 30, 33, 35, 40, 45, 50, 55, 60, 64
Window	Hamming, Hanning, Blackman, Boxcar
Frequency (w)	Pi/9 rad/sec

Table 2: Parameters for comparisons of Optimized Algorithms with boxcar window

Parameters	Minimum	Maximum
N	20	20
w	0.3491	0.3491
mag1	-56.6749	0.6081
mag2	-72.7054	0.8950
mag3	-76.9429	0.5528
n	0	19
hd	-0.0058	0.1105

Table 3: Parameters for comparisons of Optimized Algorithms with hamming window

Parameters	Minimum	Maximum
N	20	20
w	0.3491	0.3491
mag1	-88.7964	0.0215
mag2	-83.7722	0.0564
mag3	-82.1776	0.0193
n	0	19
hd	-0.0058	0.1105

Table 4: Parameters for comparisons of Optimized Algorithms with hanning window

Parameters	Minimum	Maximum
N	20	20
w	0.3491	0.3491
mag1	-130.3180	0.0582
mag2	-100.2970	0.0436
mag3	-109.6586	0.0534
n	0	19
hd	-0.0058	0.1105

Table 5: Parameters for comparisons of Optimized Algorithms with blackman window

Parameters	Minimum	Maximum
N	20	20
w	0.3491	0.3491
mag1	-112.8060	-1.9287e-15
mag2	-112.7156	5.0355e-04
mag3	-114.1927	0.0031
n	0	19
hd	-0.0058	0.1105

Comparison of magnitude response with GA, PSO & HYBRID on the basis on the different windows.

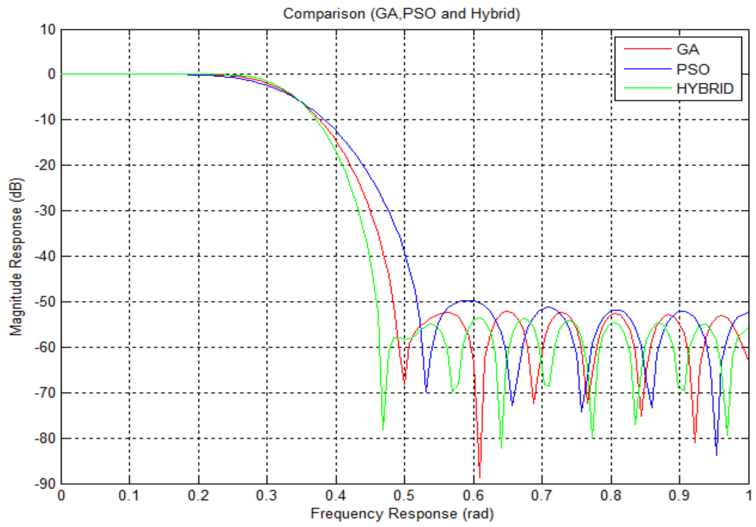

Figure 5: Magnitude Response with hamming

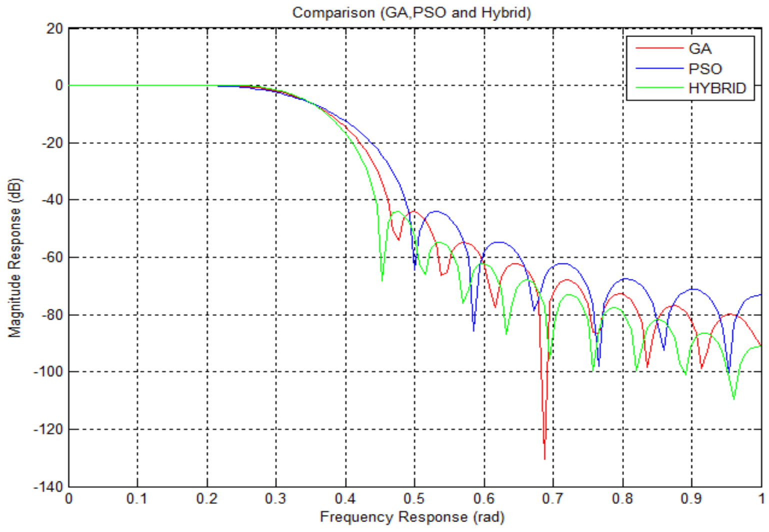

Figure 6: Magnitude Response with hanning

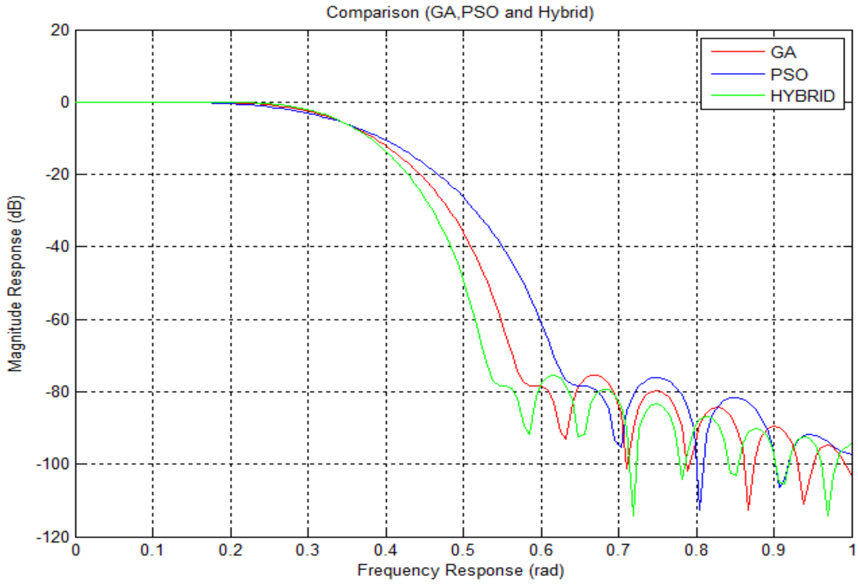

Figure 7: Magnitude Response with blackman

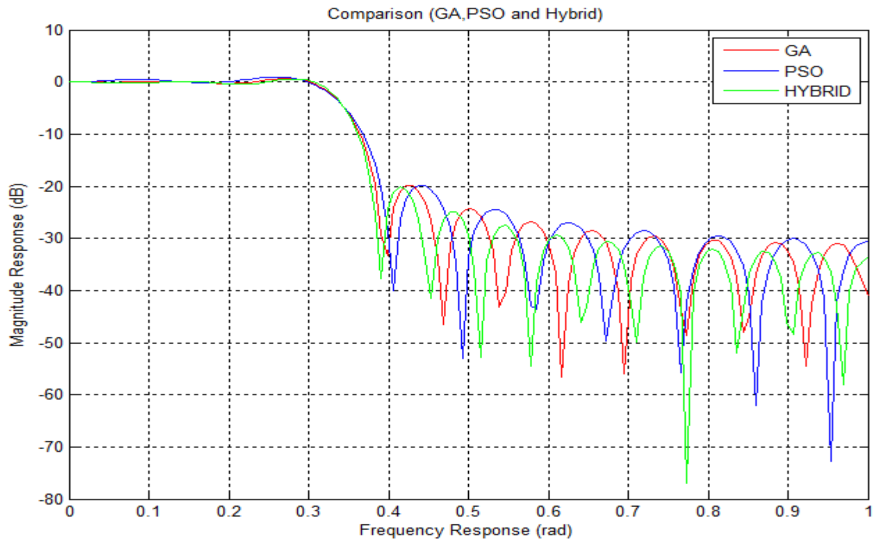

Figure 8: Magnitude Response with boxcar

Comparison of magnitude response with GA & PSO with previous results at the same order of the filter.

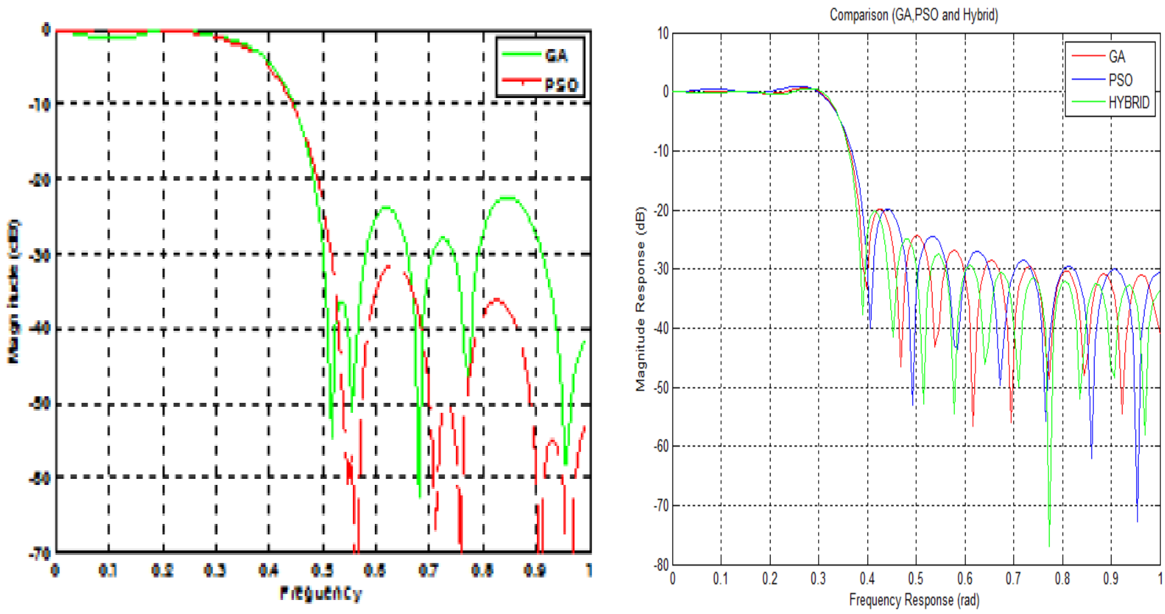

Figure 9: Compare the previous results and desired results at the order 20

IV. Conclusions

An alternative approach for FIR filters design using Hybrid of GA & PSO. Extensive results justify that the proposed algorithm with boxcar window provides the better results as compared to GA and PSO with different windows in the form of magnitude response of the FIR filter. With boxcar window, the magnitude response of the FIR filter is early goes to ideal magnitude response.

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