Comparative Evaluation of FIR Filter Design with Genetic Algorithm and Particle Swarm Optimization

Anita Suman , Parveen Kumar , Asha Rani

Abstract

The paper presents a viable methodology for designing linear phase digital FIR filter using particle swarm optimization and genetic algorithm. Evolutionary approach is a better choice than classical gradient based approaches as these are not efficient enough for accurate design. In this paper comparative analysis of FIR filter has been done using genetic algorithm and particle swarm optimization and it is found that results using PSO are better than genetic algorithm.

FIR filter design involves multi parameter and multi-modular optimization. We can use different optimization techniques to determine the impulse response coefficient of a filter to meet the characteristics of ideal frequency response. Comparison of simulation results depicts the optimization effectiveness of the particle swarm optimization algorithm over the genetic algorithm optimization techniques for solving non-differentiable, multi modal, highly non-linear, and constrained FIR filter design problems.

Now a days, digital signal processing is the vital part of the human life, due to its various applications like telecommunication, consumer electronics systems, biomedical systems, speech processing, image processing, military and defense electronics systems, aerospace and automotive electronics systems. Digital filters can be applied to very low frequency signals occurring in like biomedical and seismic applications very efficiently

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I. INTRODUCTION

Filtering is a type of signal processing. The important feature of filters is that they suppress some aspects of signals completely or partially. Filters can be designed using different technologies. The same transfer function can be realized in several different ways. The mathematical properties of the filter are the same but the physical properties might be quite different. The function of a digital filter is that It directly implements a mathematical algorithm corresponding to the desired filter transfer function. Most of the time the components in different technologies are directly similar to each other and fulfill the same role in their respective filters. Digital filters have digital components which operate on digital signals. With the digital filter, target of a lower pass band ripple higher stop band attenuation and faster transition can be achieved [1-2].

Digital Filters are of two types:

1. FIR filter
2. IIR filters

Finite impulse response (FIR) digital filters are opted for their features such as guaranteed stability, linear phase and low coefficient sensitivity [3].

However, the disadvantages FIR filters are the large number of arithmetic operations involved in their implementation which increases power consumption and reduces its speed [4]

2. METHODS OF FILTER DESIGN

FIR filters are particularly useful for applications where exact linear phase response is required. The FIR filter is

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implemented generally in a non-recursive way which guarantees stability. FIR filters consist of only zeroes. FIR filters are filters having a transfer function of a polynomial in z-plane. Frequency response and magnitude characteristics are determined by all the zeros in the z-plane.

Z transform of N point FIR filter is given by:

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

For n = 0,1,………N (i)

Where N is the order of filter having N+1 number of coefficients

FIR filter design consists of two parts

1. Approximation stage
2. Realization stage

In the approximation stage the specifications are taken and a transfer function is determined accordingly by the four steps mentioned below:

(i) A desired or ideal response is chosen, generally 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.

In the realization stage, the structure to implement the transfer function is chosen which may be in the form of circuit diagram or in the form of a program.

There are three well-known methods for FIR filter design as follows:

1. The window method
2. The frequency sampling method
3. Optimal filter design method

3. Objectives of the work

1. FIR filter has been designed using MATLAB which consists of three parts:
   a. Filter specifications
   b. Genetic algorithm and Particle swarm optimization parameters
   c. Graphical visualization.
2. A comparative analysis of results of FIR filter design using genetic algorithm and particle swarm optimization has been done.

Fitness function has been taken as

$$E(\omega)= G(\omega)\,[H_d(\omega)-H_i(\omega)]$$

Where

$G(\omega)$ is the weighting factor

$H_d(\omega)$ is the desired response of the filter

$$H_d(\omega) \begin{cases} = 1 & \text{for } 0\le \omega \le \omega c \\ = 0 & \text{otherwise} \end{cases}$$

$H_i(\omega)$] is the actual response of the filter

Fitness function has been optimized using genetic algorithm and particle swarm optimization

4. Genetic Algorithm

Genetic algorithms were invented by John Holland in the 1960s and were developed by Holland, his students and colleagues at the University of Michigan in the 1960s and the 1970s.

The traditional theory of GAs, which was formulated in Holland in 1975, assumes that, at a very general level of representation, GAs work by discovering, emphasizing, and recombining good "building blocks" of solutions in a highly parallel fashion. Good solutions have a tendency to be comprised of good building blocks - combinations of bit values that give higher fitness on the strings in which they are present.

Genetic Algorithm optimizers are robust, stochastic search methods, formed on the concepts and principles of natural selection and evolution. As an optimizer, the powerful heuristic of the genetic algorithm is effective in solving complex, combinatorial and related problems. GA optimizers are especially viable when the objective is to locate an approximate global minimum in a high-dimension, multi-model function domain, in a near-optimal manner [4].

These algorithms are derivative-free, which means functional derivative information is not required to search a set of parameters that optimize a given objective function. Rather, they depend only on repeated evaluations of the objective function, and after each evaluation the subsequent search

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direction follows certain heuristic rules.

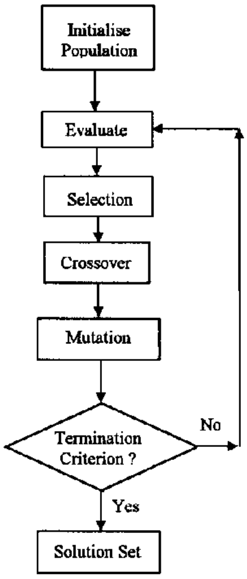

Fig 1: Flow Chart of Genetic algorithm

The optimum solution is acquired by examining new solutions which incorporate three genetic operations: reproduction, crossover, and mutation in a specific domain where the fittest survive [5].

Three main steps are there for genetic algorithm:

1. Initialization of population
2. Evaluation of fitness function
3. Generation of new population.

In random initialization of population, the initial population is created randomly [9]. An individual is represented by a fixed-length binary bit string, known as a chromosome. In evaluation of fitness function all the individuals of the initially created population are evaluated by means of a fitness function. A genetic pool is created in the next step by using the fitness function in the next step. A new population is created after evaluating the fitness of the individuals of the initial population. New generation is created basically in three stages namely reproduction, crossover and mutation. The overall aim of this step is to obtain a new population with individuals which have high fitness values [6].

5. Particle Swarm Optimization

This paper presents the power of the stochastic global optimization technique known as particle swarm optimization. Particle swarm optimization was developed by Kennedy & Eberhart [7, 13] and was published in 1995. It is a simple, computationally efficient optimization method, and population-based stochastic search which is based on a social-psychological model of social influence. Social learning individuals follow a very simple behavior; they emulate the success of neighboring individuals' emergent behavior.

PSO does not use the gradient of the problem being optimized, which means PSO does not need the optimization problem to be differentiable as is required by classic optimization methods such as gradient descent methods. Therefore PSO can also be used on optimization problems which are noisy, partially irregular and change over time.

PSO is initialized with a group of random particles (solutions) and then searches for optimum value by updating the generations. In each iteration, each particle is updated by following two "best" values [7]. The first one is the best solution (fitness) it has achieved so far. This value is known as 'pbest'. The second best value is the best value, obtained so far by any particle in the population that the particle swarm optimizer tracks. This best value is a global best and called 'gbest'. When a particle takes part of the population as its topological neighbors, the best value is a local best and is called 'lbest' [8].

The particle updates its velocity and positions with following equations:

v[] = v[] + c1 * rand() * (pbest[] - present[]) + c2 * rand() * (gbest[] - present[]) (ii)

present[] = present[] + v[] (iii)

where

v[] = the particle velocity

present[] =the current particle (solution)

rand() is a random number between (0,1).

c1, c2 are learning factors. Usually c1 = c2 = 2

One of the advantages of PSO is that PSO take real numbers as particles [11]. It is not like genetic algorithm, which needs to change to binary encoding.

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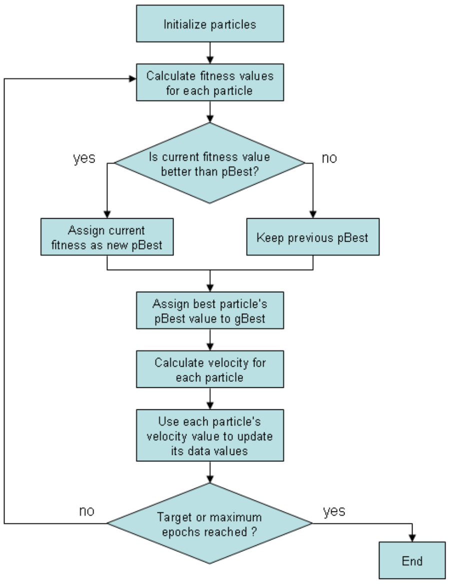

Fig 2: Flow Chart of Particle Swarm Optimization

I : Parameters used in Algorithms

Parameters	Genetic algorithm	
Population size	150	150
Crossover	0.8	------
Mutation	0.5	-------
Order of filter	31	31
Generations	6000	6000
C1 and C2	---	1.25 and 0.25
Vmin-Vmax	---	0.4 -0.9
Number of samples	512	512

The pseudo code of the procedure is as follows:

For each particle

Initialize particle

END

Do

For each particle

Calculate fitness Function value

If the fitness function value is better than the best fitness value (pBest) in history

set current value as the new pBest

End

Choose the particle with the best fitness value of all the particles as the gBest

For each particle

Calculate particle velocity according equation (ii)

Update particle position according equation (iii)

End

While maximum iterations or minimum error criteria is not attained

Particles' velocities on each dimension are held to a maximum value V_{max}. The stop condition is the minimum error requirement or the maximum number of iterations the algorithm executes [12].

6. RESULTS and DISCUSSIONS

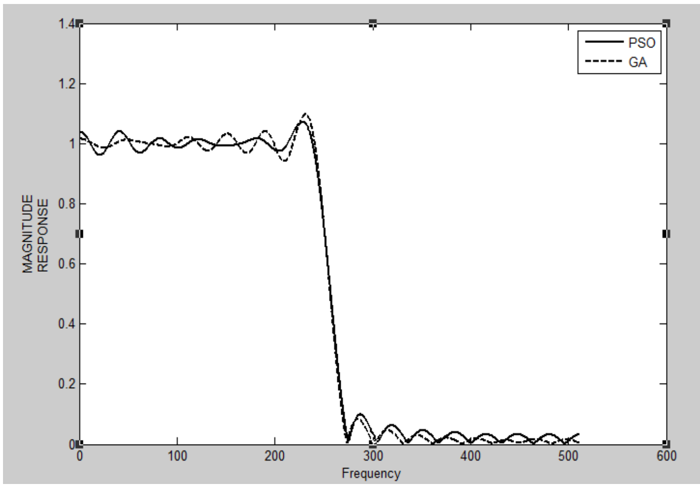

Fig 3: Low pass FIR filter response with GA and PSO

A performance analysis of FIR filter using genetic algorithm and particle swarm optimization clearly concludes that results with particle swarm optimization are better than genetic algorithm. The magnitude and gain plats have been used for the analysis. Thus, the PSO may be used as a good optimizer for obtaining the optimal filter coefficients in any practical digital filter design problem of digital signal processing systems. Better results have been obtained with increase in number of coefficients of the filter and by modifying the values of learning factors

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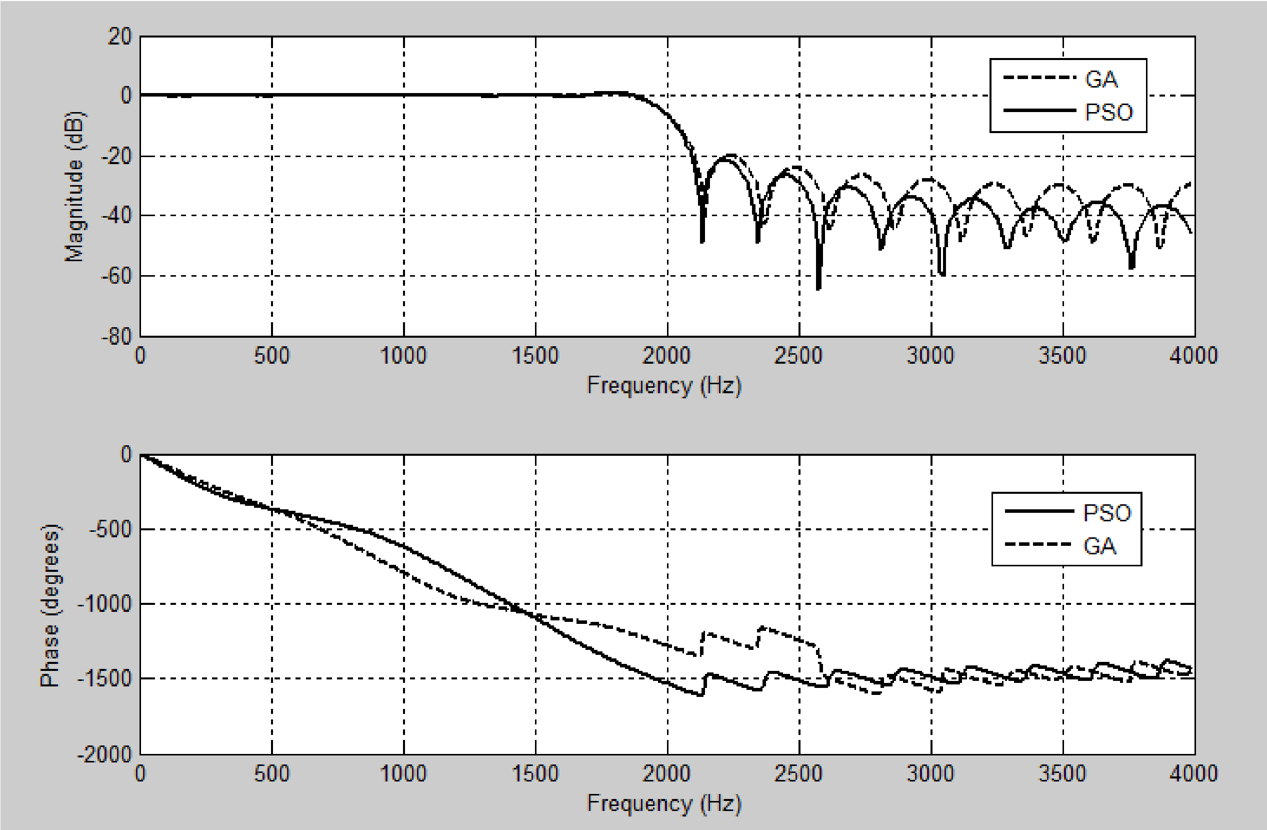

Fig 4: Gain plot and phase response of FIR filter using GA and PSO

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