Low Pass IIR Filter Design using Hybrid PSO-GSA Optimization Algorithm

Sukhchain Singh[1], Er. Mandeep Kaur[2]&Er.Dipti Bansal[3]
[1]P.G Student, [2]Asst.Professor, [3]Asst.Professor
Department of ECE, Punjabi University, Patiala Punjab, India

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ABSTRACT *Digital filter design is approximation of desired digital filter with a filter with a rational transfer function. Many approaches were proposed in this area due to its popularity and better performance, mostly used optimization algorithms are PSO, GA etc. But it is analyzed that these algorithms either have better population updation strategy or better selection strategy, Many rare algorithms exist which provide a better solution with better selection and updation property. In the proposed work a hybrid model of the PSO and GSA approach is developed. As PSO and GSA has individually have each single property of better selection and updation. The simulation results show that designing of digital filter with use of hybridization of GSA and PSO algorithms gives better results in terms of group delay, magnitude response and signal error.*

Keywords:*Optimization algorithm. FIR filters, GSA, PSO, IIR filters*

I. INTRODUCTION

In Digital Signal Processing (DSP) the Basics Digital filters plays the vital role. Due to the efficient performance of these filters, the role of DSP had started increasing. There are two significant uses of filters: first on is signal separation and second one is signal restoration. It is required to separate the signal when the contamination in the signal is encountered such as noise, interference etc. For instance, consider equipment that can be used for analyzing the electrical variations in the heart of a baby (EKG) who is in womb. Due to the interference of mother's heart beat, the raw signal of baby's heart beat get distorted. To separate these signals, filter can be used so that the required signal can be extracted. In case if the signal is distorted then signal restoration technique is implemented. For instance, consider that voice recording is done with the bad quality of recorder and it is require that filter the signal to show the actual voice with good quality. One more instance is making an image blur free if the image is taken from non focused lens and shaky camera. To remove these problems analog or digital type of filter can be used. It is difficult to choose out of these filters. Analog filters are cheaper, quicker in response and comprised of wide range for amplitude and frequency variation. On the other hand digital filters are much better than analog filters. There are number of technical uses in the digital signal processing (DSP) areas like imaging, digital video, data communications and voice communications. Digital signal processing techniques can handle the digital communications system design. In continuous-time systems both the input and output are continuous-time signals and Analog filters belong to such systems. Input and output of digital filters are discrete time signals. Digital filters are used to implement the electronic digital circuits which perform the various tasks of addition, delay, multiplication. Analog signals can be implemented by the amplifiers, capacitors, inductors. It is kind of impulse response, digital filters are classified into two parts. FIR and IIR filters. In signal processing, the both functions of dynamic systems present the output when presented with a brief input signal, called an impulse. Impulse response refers the reaction of dynamic system which response to some external change. FIR is the type of digital filter. The impulse response settles to zero within a finite amount of time. FIR filter is the nonrecursive filter because they do not require any feedback. In the IIR filters obeys the non zero over an infinite length of time. IIR filter is known as recursive in nature they required feedback signal Impulse response never dies. It has some useful properties, which gains a lot of preferences over the IIR filter.

II. PROBLEM FORMULATION

The major use of the Digital filters are in speech processing and audio processing, radar and telecommunication systems, and biomedical signal processing etc. If literature is to study it is concluded that in comparison with analog filters, digital filters have many advantages. Digital filters are flexible and programmable, better performance, resistance to manufacturing variations or aging, and not drifting with temperature or humidity. Digital filter design is approximation of desired digital filter with a filter with a rational transfer function. In present system there are two categories of digital filters one is direct and other one is indirect. Butterworth filter, chebyshev filter of different types, and transform back to z plane. These types of filters needs too much pre-knowledge to process the signals and has poor performance. Other types are direct approaches these types of filters converts problem of designing to optimization of a fitness function with respect to coefficients of a rational transfer function. Many approaches were proposed in this area due to its popularity and better performance, mostly used optimization algorithms are PSO, GA etc. But it is analyzed that these algorithm s either have better population updation strategy or better sel ection strategy, many rare algorithms exist which provide a better solution with better selection and updation property. So it is suggested to develop an algorithm which can provide better opportunity to get best coefficient that can provide better fitness for the filter designig

III. PROPOSED WORK

As it is analyzed from the literature study that most of the metaheuristic approaches used to achieve optimum result for a solution are either have better population updation strategy or better selection strategy, So it was suggested to develop a algorithm which can provide better opportunity to get best coefficient that can provide better fitness for the filter designing. In the proposed work a hybrid model of the PSO and GSA approach is developed. PSO 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. Gravitational Search Algorithm (GSA) is based on the law of gravity. Each candidate of the population is considered as an object (mass). Each object has four specifications i.e. active gravitational mass, passive gravitational mass, inertia mass and position. As PSO and GSA has individually have each single property of better selection and updation. To achieve the objectives simulation is done in MATLAB. The fitness function works on achieving signal with less noise and better smoothness by upgrading the coefficients of the filter. The simulation will have designing of digital filter with use of PSO and GSA individually and then hybridization of both the algorithms will be done. The performance analysis of the each system will be done and then comparative analysis will show the improvement of the proposed model. The methodology of proposed work is as follows:

1. Passing the input signal to the system is the first step of this work. In this a signal is generated and noise is added to it. Then the noisy signal is passed as an input signal to the system.
2. In this step the indirect filter is applied to the noisy signals and for this purpose the Butterworth filter is used.It is a signal processing filter that has frequency response as flat as possible in the pass band. For this reason, it is also referred as a maximally flat magnitude filter. "On the Theory of Filter Amplifiers" by the British engineer Stephen Butterworth showed the description of this in 1930. For the implementation of a specific stop band, a higher order is required by it because it has slower roll-off. It provides a better linear phase response than chebyshev and elliptic filters in the pass band.
3. Next step is to evaluate the fitness function. The fitness function is measured in the terms of error.
4. The initialization of parameters takes place in this step. The parameters such as size of the population, number of iterations for optimizing the problem.
5. Then the PSO, GSA and Hybrid PSO-GSA is implemented on the basis of the coefficients of the filters. On the basis of the observed output from the optimization mechanism the fitness function is updated respectively.
6. Here the fitness function is measured again. And if the improved fitness function is achieved then the selection of best optimum coefficient selection is done.
7. In this step, the performance calculation is done.

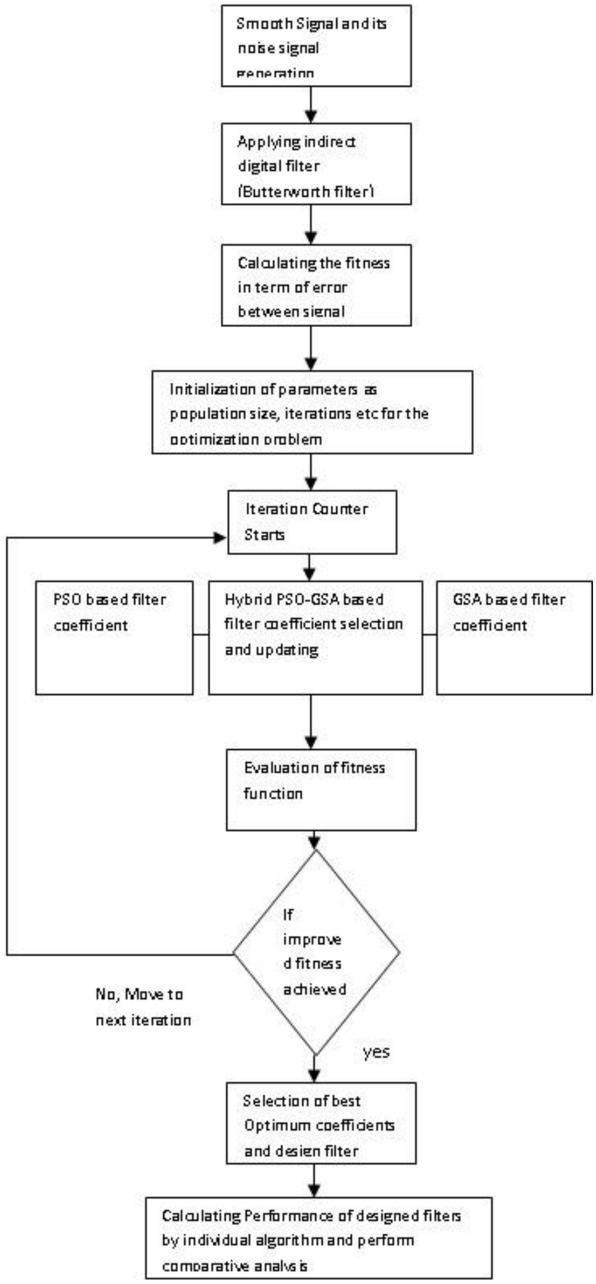

Figure 1 Framework of propose work

IV. RESULTS

This study is organized to design the digital filters for improving the quality of the signals. For this purpose, the Butterworth filter is applied to the signals. Along with this the hybrid optimization mechanism i.e GSA+PSO is applied to extract the coefficients of the signals. The performance of the proposed work is evaluated in the following terms:

1. Magnitude Response
2. Phase Response
3. Group Delay
4. Fitness

Magnitude response: The magnitude response is a parameter that is used to measure the variation among magnitude response of desired filter and designed filter for signal processing. Following is the formulation of magnitude response or magnitude error.

$$H_d(f) = \begin{cases} 1 & |f| < f_c \\ 0 & f_c < |f| < 0.5 \end{cases}$$

Group Delay: In order to avoid the phase distortion, it is mandatory that applied filter must have linear phase response in pass band and transition band of the signals. The linear phase response is considered as an equivalent to the group delay in pass band. The evaluation of group delay is as follows:

$$\tau(\mathrm{f}) = -\frac{1}{2\pi}\frac{\mathrm{d}}{\mathrm{df}}\{\varphi(\mathrm{f})\} \quad (5.2)$$

Where, $\varphi(\mathrm{f})$ defines the phase response of the designed filter. Similarly, the constant group delay can be written as follows:

$$\mathrm{c}_2(\mathrm{a}) = \sum_{\mathrm{f}\in\mathrm{P}+\mathrm{T}} \Big(\tau(\mathrm{f}) - \mathrm{medium}\big(\mathrm{t}(\mathrm{f})\big)\Big) \quad (5.3)$$

Where, T defines the set of equidistant frequencies in transition band. By reducing the above terms the group delay in transition band and pass band can be maintained.

Phase Response: The phase filters are comprised of zeros and poles within its unit circle. The minimum phase lag property is considered as one of the major feature. The phase response can be measured as follows:

$$c_3(a) = (\#of\ zeros\ outside\ UC) \quad (5.4)$$

Fitness: It defines the average error of a signal. It is a difference between the estimator and the estimated value. It has used to estimate the quality of the proposed technique with respect to the traditional technique. Its value always is non-negative and closer to zero value is better. The fitness of proposed work is evaluated is as follows:

$$f = \sum \frac{S_o - S_f}{N} \qquad (5.5)$$

Where S_o denotes the original signal, S_f denotes the filtered signal and N refers to the length of the signal.

The graph in figure 2 depicts the comparison of magnitude response among Initial filter, filter by applying PSO, filter by applying GSA and filter after applying Hybrid optimization.

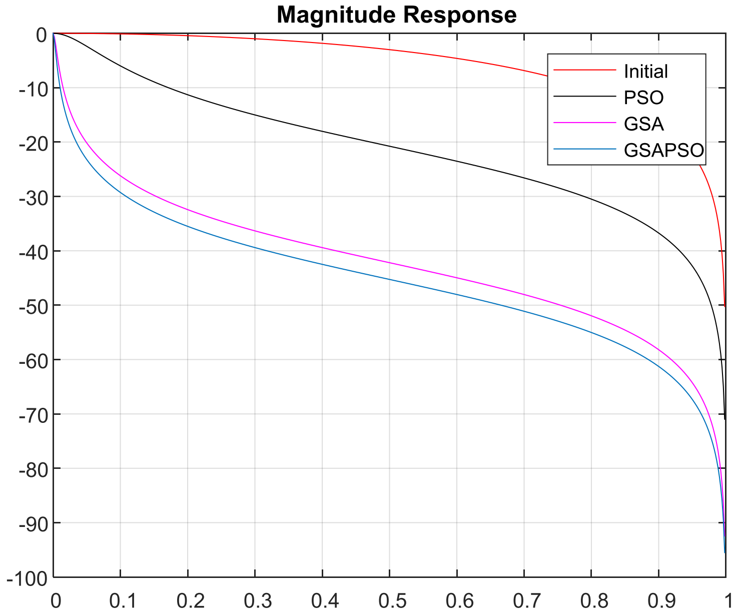

Figure 2 comparison Analysis of Magnitude Response among used optimization technique

The comparison analysis defines that the proposed hybrid optimization based digital filter has the most effective magnitude response in comparison to the individual PSO and GSA optimization techniques based digital filters.

The graph in figure 3 represents the comparison of fitness function achieved by applying PSO, GSA and hybrid optimization techniques. The y axis in the graph calibrates the data for defining the value of the fitness function. On the basis of the observations from the comparison graph it is proved that the fitness value achieved by the hybrid optimization technique is quite effective than other optimization techniques.

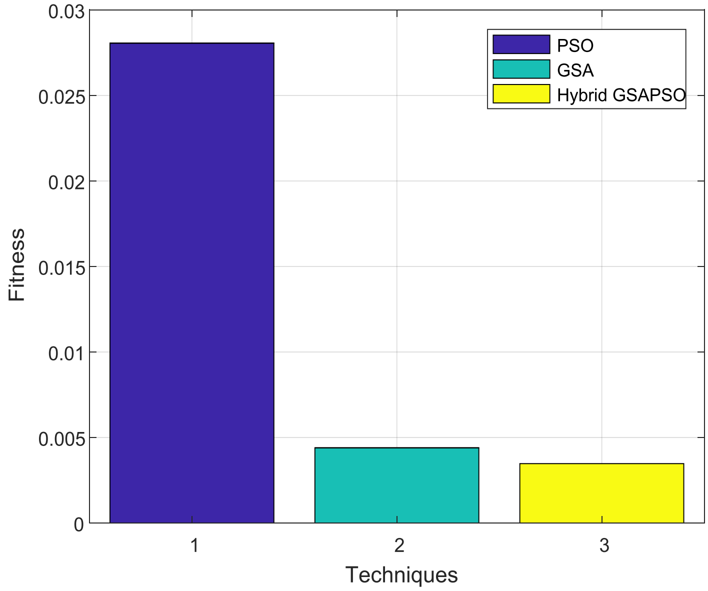

Figure 3 Comparison analysis of the fitness function on the basis of the considered optimization techniques

The comparison of obtained fitness by using PSO, GSA and hybrid optimization technique on the basis of the number of iteration is represented in the graph of figure 4. The graph explains that the fitness value achieved by the proposed hybrid optimization technique is lower than the fitness value achieved by PSO and GSA optimization. The x axis in the graph delineates the number of iterations i.e. from 0 to 100 and the y axis defines the value for fitness function i.e. 0.005 to 0.045.

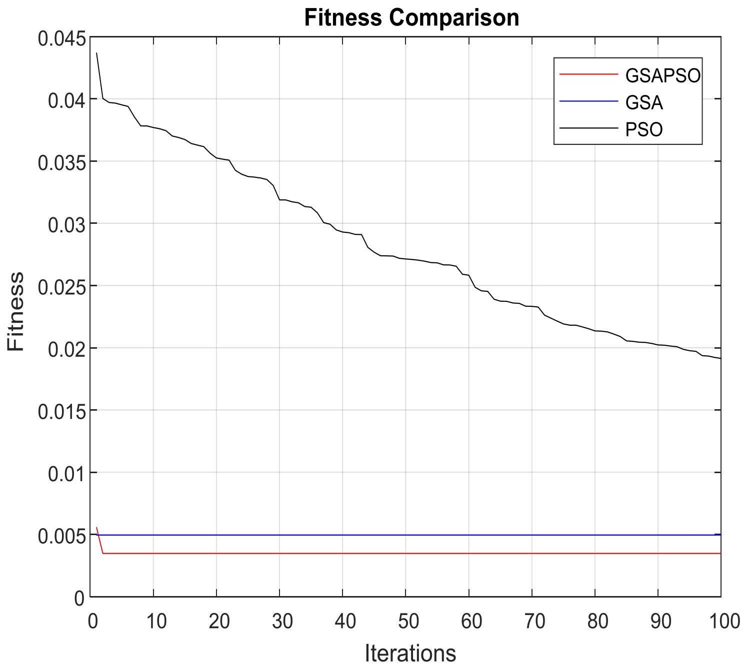

Figure 4 Comparison of fitness function with respect to the number of iterations

The graph in figure 5 delineates the comparison of proposed and other optimization techniques based digital filters in the terms of Group Delay. The curve in black colour refers to the group delay of PSO based digital filter; the curve in blue delineates the group delay of GSA optimization based digital filter and the curve in red colour defines the group delay of hybrid optimization technique. The graph explains that the group delay of hybrid optimization is better and lesser than other optimization techniques.

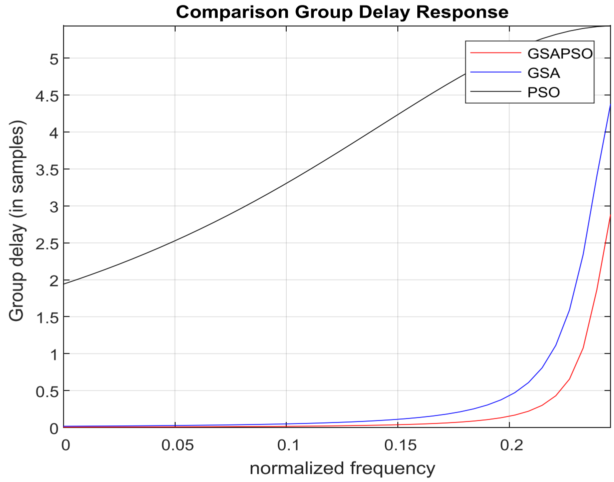

Figure 5 Comparison analysis of Group Delay on the basis of the optimization techniques

V. CONCLUSION

The digital signal processing has gain the popularity among various domains due to its high use in various applications. As the signals travels through a communication medium, thus there is possibility that the noise can effects the signals. And if the noise is entertained in the original signals then it is possible that all the actual information of the original signal gets corrupted. Thus the filters are developed to process the noisy signals in order to eliminate the effect of the noise from the signals. The digital filters are specifically designed by using various filtration techniques to filter the signals.

This study investigates that the traditional optimization techniques applied for designing the digital filters were not found to be quite effective. Therefore a novel digital filter is designed in this work by using the hybrid optimization technique i.e. PSO and GSA. The major objective behind applying the hybrid optimization technique is to extract the optimized coefficient of the signal for filtration procedure. The performance evaluation is one in the terms of magnitude response, phase response, frequency response and group delay. Along with this the fitness function of proposed work is also compared with the fitness function of the traditional digital filtration system. On the basis of the results, it is concluded that the proposed hybrid optimization based digital filter outperforms the traditional digital filters with respect to the considered performance parameters.

In future the present work can be enhanced by applying the multi objective systems in order to retain the smoothness in the filtered signals along with the reduced error rate.

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