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Review on FIR Filter Designing by Implementations of Different Optimization Algorithms

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Abstract-FIR filter is multimodal design problem. Due to multimodal and non-linear nature of error surface conventional gradient based technique are not efficient for filter designing. So numerous authors have been solved the filter design problem by implementation of different global optimization algorithms and achieve promising results. In this paper performance of various implementation techniques such as genetic algorithm, differential evolution algorithm, particle swarm optimization, adaptive differential evolution particle swarm optimization and cat swarm optimization are discussed and compared. This paper presented a review on optimal design of FIR filters using different optimization techniques.

Keywords: Optimization, FIR filter, genetic algorithm, differential evolution algorithm, particle swarm optimization, adaptive differential evolution particle swarm optimization, cat swarm optimization, pass band ripple, stop band attenuation.

I. INTRODUCTION

Today digital signal processing (DSP) has a wide range of applications in the fields of communication, pattern recognition, image processing, etc. Because of having numerous advantages such as more flexibility, good performance, better time response, environment stability and lower equipment production costs than traditional analog techniques it become one of popular application area in electronic engineering and need more advancements in present era. These all new DSP advancements caused from the advances in digital filtering. Digital filter is main component in DSP and it is define as a system that performs mathematical operations on a sampled discrete time signal to shrink or boost certain aspects of that signal. It is the digital filter which performs all basic function in DSP such as filtering, addition of signal or to separation of signal etc. Nowadays due to advancement in technology filters with high speed and less error are needed to design. Due to these requirements filter design become a popular search area. There are two basic types of digital filters, Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters. FIR digital filter have many benefits like guaranteed stability, free from phase distortion and low coefficient sensitivity and simplicity make it preferred in most cases.

There are various traditional methods exist for digital FIR filter design. Out of those one is design of filter by making use of optimization algorithms. This method has an amazing ability that is it gives options of using of different optimization algorithms and improperness in design directly depend upon performance of algorithms. Initially this method has given by Parks and McClellan by using a simple iterative commuter program and is termed as PM method for filter designing [1], [2]. Later this method is further modified by replacing use of simple program with optimization algorithms. In initial genetic algorithm was used for all types of filter design [3], [4]. This is followed by use other algorithms like stimulated annealing, artificial bee colony, and differential evolution by different authors [5]-[7]. Then practical swarm optimization algorithm which is most popular algorithm proposed by Kennedy and Eberhart [8] has implemented for the filter design [9]. After this hybrid algorithms and modified algorithms has been developed from basic type of algorithm for further improvements in filter designs. Uses of improved particle swarm optimization, adaptive evolution particle swarm optimizations for the filter designing are witness of these trends [10]-[12]. Recently a novel algorithm named Cat swarm optimization has been implemented for design of filter for achieving more effective results [13].

II. DIGITAL FILTER

In simple words digital filter is a system which performs a mathematical operation on input signals and covert into another form. So digital filters can be represented mathematically by its characteristic equation given as

$$H(z)=\sum_{n=0}^{M} h(n)z^{-n} \quad , n=0,1\ldots M \qquad (1)$$

where M is the order of the filter which has (M+1) number of coefficients and h(n) is the filter's impulse response. [14] H(z) is termed as transfer function it is the what which is multiplied by filter to input signal to convert into output. 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. For linear phase FIR filter h(n) is symmetrical so only half of coefficient are need to calculate. For design of filter using optimization algorithm the filter design problem is converted into an optimization problem. That is one fitness function is calculated which is related to error of designed filter from ideal filter. Then this fitness function is optimized to find best fit individuals. The error function is a difference between the ideal filter response and practical response and can be calculated as

$$E(w) = G(w)(H_d(e^{jw}) - H_i(e^{jw})) \qquad (2)$$

Where H_i (w) correspond to ideal filter response, G (w) is weighting function, H_d (w) correspond to actual filter response calculated using given variables [9].
H_i (w) can be any type of ideal filter that is it can be low pass, high pass, band pass or band reject filter .By using different type of H_i (w) corresponds type of filter can be designed.
Fitness function which is to minimized using optimization algorithm is normally maximum values of this error function and can be represent as in equation (3) simplest form as

$$FIT = \min(\max |E(w)|) \qquad (3)$$

In this way by using FIT as fitness function filter design problem can be converted into optimization problem which can be solve by any of meta- heuristic algorithms. Accuracy of designed filter directly depends upon performance of algorithm that is "better is algorithm more accurate filter design can be achieved". However this basic form of fitness function shown in equation (3) has some disadvantage so it is improved by number of authors and gives rise to several versions of fitness functions for optimal design of filter. In this way there are two modifications available for better filter design one is use of better fitness function which gives more control on filter parameters and second is use of better optimization algorithm which has better performance. Both approaches are used by numerous authors and give rise to number of research work available in literature. Out of which some work of using different optimization algorithm is discussed in this work.

III. OPTIMIZATION TECHNIQUES EMPLOYED

A. Genetic algorithm

Genetic algorithm (also known as real code genetic algorithm) is based on the concept of "survival of the fittest" [4]. This process equivalent to genetic recombination and mutation are employed in order to promote the evolution of a population that best satisfies a desired goal. The individual which are to be optimized are considered as chromosomes. The algorithm starts with an initial population representing random chromosomes solutions. Each individual in the population is awarded a score based on its performance. The individuals with the best scores are most likely to be selected to yield a new generation. The selected individuals are used to yield a new population based on two main genetic operators, crossover and mutation. In crossover, two individuals are used to yield two new individuals by genes exchange between the two selected individuals. Random mutation is also applied to add some diversity to the population. The produced children are also scored, with the best performers are likely to be parents in the next generation. The process is repeated until achieving a termination criterion. Same approach is used in filter designing which best fit filter coefficient are find using given fitness function

B. DE algorithm

The differential evolution algorithm (DE algorithm) is a method based on the principles of GAs, but with crossover and mutation operations that work directly on continuous-valued vectors [6]. The main difference in constructing better solutions is that GAs relies on crossover, whereas the DE algorithm relies on the mutation operation. Crossover is based on selection of best among two and mutation is related to adoption best quality from both to form a new child which will have best quality of both parents. Main aim of this algorithm is also to find individuals which are most suitable for given fitness function but have advantages like it finds the true global minimum of a multimodal search space regardless of the initial parameter values and it has fast convergence, As it has batter performance then standard GA so batter filters are obtained by implementation of this on same fitness function.

C. Particle swarm optimization

Particle swarm optimization (PSO) is a flexible, robust population-based stochastic optimization technique with implied parallelism, which can easily handle with non-differential objective functions [8]. PSO is developed through simulation of bird flocking in multidimensional space. Bird flocking optimizes a certain objective function. Each particle (bird) knows its best value so far (pbest). This information corresponds to personal experiences of each particle. Moreover, each particle knows the best value so far in the group (gbest) among pbests. Namely, each particle tries to modify its position using the two type of information one is the distance between the current position and the pbest and second is the distance between the current position and the gbest. Using this information each bird modifies its velocity toward these values. So a swarm of bird tried to reach at best suitable value hence optimized the function. This algorithm has a number of advantages over the other exiting algorithms such as less chance of frailer, more accuracy and can also be used for filter design to remove weakness of design obtained by using of other algorithms.

D. Adaptive DEPSO (ADEPSO)

DEPSO is a hybrid version of DE evolution and PSO which utilizes the benefits incurred in both the algorithms individually. DEPSO approaches in terms of robustness and accuracy of the optimization algorithms. The DEPSO is further modified with the use of fitness based adaptive cross over rate used for the cross over purpose. The one having better fitness value should have more probability of being transferred to the trial vector rather than the one having lower fitness value. So using this concept cross over rate is calculated separately for each and every element of the population set and a new version is obtained named as adaptive DEPSO. ADEPSO have batter performance then basic algorithms. This has been proposed by Vasundhra et

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al. [13] and filter designed by implementations of these give rise to promising improvements in filter design.

E. Cat swarm optimization

The algorithm imitates the natural behavior of cats. Cats have a strong curiosity towards moving objects and possess good hunting skill. Even though cats spend most of their time in resting, they always remain alert and move very slowly. When the presence of a prey is sensed, they chase it very quickly spending large amount of energy. These two characteristics of cat are resting with slow movement and chasing with high speed and are represented by Seeking and Tracing modes, The CSO algorithm reaches its optimal solution using two groups of cats, i.e., one group containing cats in seeking mode and the other group containing cats in tracing mode. The two groups combine to solve the optimization problem and algorithm achieves batter performance. Implementations of cat swarm optimization give rise to improvements in filter design spatially reduction in stop band ripple factor.

IV. RESULTS AND DISCUSSION

This section presents the simulations results performed in MATLAB R2013a for the design of FIR filters. Order (N) of filter is each case is taken as 20, which results in the number of coefficients as 21. As in linear phase FIR filer coefficient are symmetrical only half of coefficients has been calculated in this problem. The sampling frequency is equal to 1Hz and the number of frequency samples is taken equal to 128. Each algorithm is run for fixed number of iterations (200) to obtain results. Although any of basic type FIR filter (low pass, high pass, band pass etc.) can be obtained using given approaches by changeH_i (w) in equation (2). But only FIR design of high pass filter is discussed and compared in this paper because performance algorithm for of all other type is almost similar. For the design of 20 order high pass obtained filter coefficients h(n) by implementation of different algorithms are presented in Table 1.

TABLE I. Calculated Filter Coefficients for High Pass FIR Filters by Using Different Algorithms

h(n)	***RGA***	***PSO***	***DE***	***ADPSO***	**CSO**
h(1)= h(21)	0.0217	0.0256	0.0290	0.0295	0.0275
h(2) =h(20)	-0.0481	-0.0474	-0.0459	-0.0456	-0.0444
h(3) =h(19)	0.0062	0.0514	0.0029	0.0020	0.0032
h(4) =h(18)	0.0419	0.0400	0.0413	0.0369	0.0429
h(5) =h(17)	0.0008	0.0014	-0.0003	-0.0041	0.0010
h(6) =h(16)	-0.0590	-0.0603	-0.0600	-0.0548	-0.0582
h(7) =h(15)	-0.0000	0.0008	-0.0039	-0.0042	0.0032
h(8) =h(14)	0.1042	0.1051	0.1061	0.1031	0.1024
h(9)= h(13)	0.0004	-0.0001	-0.0006	0.0039	-0.0022
h(10)=h(12)	-0.3166	-0.3155	-0.3201	-0.3142	-0.3179
h(11)	0.4995	0.4999	0.5000	0.4920	0.4998

The coefficients are calculated up to high precision value using MATLAB R2013. But coefficients up to only 4th decimal value are shown in Table 1. Frequency response of filter designed can be obtained from coefficients and magnitude across the normalized frequency can be checked to note the amplification and attenuation across the different frequency range that is to find pass band and stop band range and behavior of filter in these bands. Magnitude responses of high pass filters having coefficients as shown in Table 1 are shown in Figure 1.

Fig. 1. Frequency Response of High Pass Filter Obtained by Using Different Algorithms

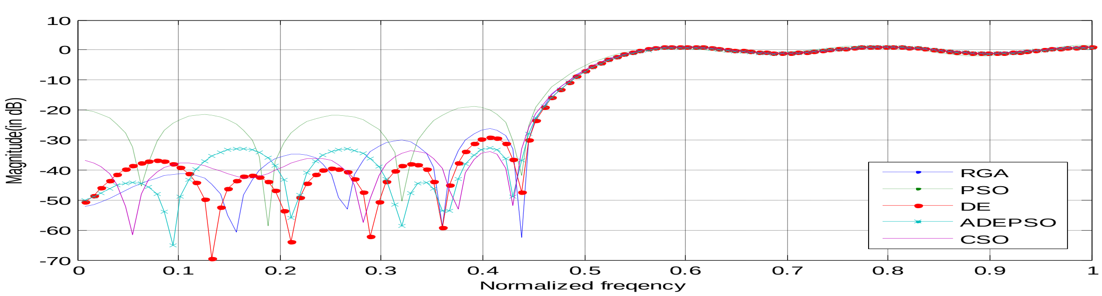

Fig. 1 show comparative plot of high pass filter obtained by applying different optimization algorithms. This figure is obtained using filter coefficients shown in Table 1 and clearly shows the results obtained using different algorithms. For comparison in performance of designed filters maximum stop band attenuation is considered. Higher is the maximum stop band attenuation (lesser is ripple) better is the performance of filter. So hybrid version ADPSO and new type of algorithm CSO are said to better performing techniques.Pass band ripple value and maximum stop band attenuation obtained in all works is compared in Table 2.

TABLE II. Comparative Summary of Parameters for High Pass Filter Obtained by Using Different Algorithms

Algorithm	Pass band ripple	Stop band ripple	Attenuation in stop band (in dB)
PM	0.066	0.0688	-23.55
RGA	0.117	0.0546	-25.25
PSO	0.122	0.0394	-28.01
DE	0.136	0.0348	-29.16
ADEPSO	0.132	0.0232	-32.68
CSO	0.132	0.0208	-33.62

Table 2 shows the effective reduction in stop band attenuation using latest optimization algorithms.That is signal will stopped more effectively in stop band and leakage noise become lesser in case of Filters obtained by hybrid and new algorithms.

It is noted that pass band ripple is least in case of PM approach which is because equal weightage was given to both pass band ripple and stop band ripple in that approach. However after this researcher feels that there is more need to control on stop band attenuation so RGA and latter techniques design filter with better stop band attenuation on compromising the pass band ripple. Significant improvement using all later RGA techniques is mainly because of performance of algorithms. Similarly other types of filter (low pass, band pass, band reject) are also can be designed using all type of algorithm and almost similar improvements are noted using various optimization algorithm. Although large number of techniques and optimization algorithm are implemented for FIR filter designed but only some popular are discussed in this paper to understand trends and future scope in digital filter designing.

V. CONCLUSION

Geneticalgorithm, DE, algorithm are good approaches for FIR filter design but PSO is most effective than these algorithms. But if use the basic type algorithms is replaced by hybrid or advanced algorithms than more enhanced results are obtained. This is because of advancement in optimization algorithms which lead to more accuracy in finding of suitable coefficients. So to achieve more improvement in FIR filter design use of more advanced algorithms is appreciated or there is need of devolvement of better performance algorithm by hybridization of exiting algorithm or introducing new type of concepts. However modification in fitness function should also possible. Mixer of both approaches gives more accurate results. Due to this reason FIR filter designs by latest approaches (ADPSO, CSO) achieve best results and these approaches can further extend in future for more improvements in filter designing.

References

[1] T.W. Parks and J.H. McClellan, "A Program For The Design Of Linear Phase Finite Impulse Response Filters", IEEE Transaction on Audio Electroacoust, vol. 20, 3, pp. 195–199, 1972.

[2] J.H. McClellan and T.W. Parks, "A Unified Approach to The Design of Optimum FIR Linear Phase Digital Filters", IEEE Transaction on Circuit Theory, vol. 20, pp. 697-701, 1973.

[3] D. Suckley, "GeneticalgorithminthedesignofFIR filters,"IET Journals and Magazines vol. 138 , pp. 234 - 238 , Jan. 1991 .

[4] A. Lee, M. Ahmadi, G. A. Jullien, W. C. Miller, and R. S. Lashkari,"Digital Filter Design Using Genetic Algorithm", IEEE International Symposium on Circuits and Systems, Monterey, CA, pp. 34–38 ,1998.

[5] N. Benvenuto, M. Marchesi and A. Uncini, "Applications of Simulated Annealing For The Design of Special Digital Filters", IEEE Transaction on Signal Processing, vol. 40, 2, pp. 323–332, 1992.

[6] N. Karaboga and B. Cetinkaya, "Design of Digital FIR Filters Using Differential Evolution Algorithm", Circuits Systems Signal Processing, vol. 25, pp. 649–660, Jan 2006.

[7] N. Karaboga, "A New Design Method Based on Artificial Bee Colony AlgorithmFor Digital IIR Filters", Journal of the Franklin Institute, vol. 346, 4, pp. 328–348, March 2009.

[8] J.Kennedy, R. Eberhart, "Particle swarm optimization," IEEE International Conference on Neural Networks, Perth, Australia, 1995, pp. 1942–1945..

[9] J. I. Ababneh, and M.H Bataineh, "Linear phase FIR filter design using particle swarm optimization and genetic algorithms", Journal of Digital Signal Processing, vol.18, 4, pp. 657–668. June 2008.

[10] S.Mandal, S.P. Ghoshal, D. Sengupta, R. Kar, and D Mandal, "Design of Optimal Linear Phase FIR High Pass Filter Using Improved Particle Swarm Optimization", International. Journal on Signal & Image Processing, vol. 03, pp. 5-9, Jan 2012.

[11] S. Mukherjee, R. Kar, D. Mdandal, S. Mondal, and S. P. Ghoshal, "Linear Phase Low Pass FIR Filter Design Using Improved Particle Swarm Optimization", IEEE Student Conference on Research and Development, Durgapur, India,Dec 2011, pp. 358-363.

[12] The MathWorks, [Online]. Available http://www.mathworks.com
[13] Nature inspired algorithms, [Online]. Available http://www.scholarpedia.com

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