ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2015

Survey Paper on Digital IIR Filter Using Evolutionary Algorithms

Sonal Dwivedi, Pankaj Shrivastav.

Department of ECE, MPCT College, Gwalior, India

Professor, Dept of Electronics & Communication, MPCT College, Gwalior, India

ABSTRACT: Over few decade digital filters has developed many applications on various fields. Basically, Filters are used to eliminate the unwanted frequencies from applied signal which have both wanted and unwanted signals. In this paper, we are using various techniques to reach our desired requirements by using evolutionary techniques such as Genetic algorithm, Taguchi optimization technique, Multi-objective evolutionary algorithm, particle swarm optimization (PSO) and FDA tool which is predefined in MATLAB. Digital filters are of two types: Infinite impulse response (IIR) and finite impulse response (FIR). Here we are verifying different objects for low-pass, high-pass, band-reject (Notch) and band-pass filters such as coefficients of filter, order of filter, multi-objects, efficiency, effectiveness, comparing results obtained from different techniques, pole-zero plots and responses. This paper represents the designing of filters with different approaches and their comparison with other to find the better most technique.

KEYWORDS: digital filters, genetic algorithm, FDA tool, PSO, multi-objects.

I. INTRODUCTION

Nowadays DSP is become a important tool and have shown rapid development in various field resulting the significant advances on digital technology, image processing, robotics, circuits fabrication, VLSI, video communication, biomedicine and many other applications. Filters are used to transmit desired frequency from the transmitted signal. Filters can be analog type or digital type. The digital filters are more forward, gives better, faster, less error and disturbances in the output. Digital filters are capable to perform various operations that world, at best, be highly difficult to pursue with analog filters. The types of digital filters are IIR filter and FIR filter. In FIR filter there is no feedback and have linear- phase characteristics. The impulse response is of finite duration and has finite terms of non-zeros. Irrespective of FIR, the IIR filter has feedback and gives better response with less compatible cost. IIR filter is suitable for lower order filter and found more targeted than FIR. In designing the IIR filter the main hindrance is to set the lowest order for the purpose of magnitude response and linear phase response. In maximum research work this problem is taken as single objective problem either they consider magnitude response or phase response. The linear-phase response has its own importance because in non-linear phase response case, it causes distortion. The cooperative co-evolutionary genetic algorithm (CCGA) can be considered to solve this multiple problem.

Various techniques do exist to design digital filters, like windowing techniques which is most popular method and very much in use. There is different kind of window functions such as Butterworth approximation, ellipse, chebyshev approximation, Kaiser etc have been developed using transformation techniques which has different ripples factors in their stop-band and pass-band. Moreover, window method have limitations that it do not have full control on frequency response, magnitude response, cut-off frequency in various frequency bands and also in other parameters. Filter designed by transformation techniques are not suitable in form of phase-response coefficient error and filter design. The researcher of filter has to compromise between various parameters specification and requirements. Therefore, most of researchers tried to develop digital filter structure method on modern optimization algorithm such as genetic algorithm, PSO, Tabu search (TS), Taguchi optimization, multi-objective GA, simulated annealing (SA), RCGA etc, to get better response and stability. So in this way number of evolutionary techniques is been developed to provide analytical or simple iterative methods to found desires.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2015

Out of various existing technique one of those is real coded genetic algorithm is natural coding technique used for coding in search space solution when tracking optimization problem [3]. In optimization process, the function is calculated by mean-square error and ripple magnitudes of pass-band and stop-band. Optimization is method of making something more reliable, efficient, perfect as possible as and minimize the error rate, computational cost or to maximize the effectiveness of something. As linear-phase filter basically considered in FIR (non-recursive) filter which have constant group delay all over the baseband. Whenever filters are required of high selective, a very high filter order is needed which transform the filter costlier and non-practical. So to remove this factor, attempt made to develop various methods. Filter designed by Taguchi optimization [2] with the motive to design filter which can simultaneously satisfy all the multi-objects such as frequency response, linear-phase and least possible group delay. Goldberg presented and developed a mathematical model Genetic algorithm. Lately it been used by some researchers to design IIR filter with coefficient of low-pass filter. To test the procedure MATLAB is implemented with optimization techniques, genetic algorithm whose result is found to be useful, according to requirement and very encouraging. Notice that in transfer function of IIR and FIR which consist of numerator and denominator both are polynomials, so they have roots. The roots of numerator called zeros and that of denominator called poles. Due to presence of poles in the transfer function the stability of filter should consider in the optimal design as it plays important role in designing pole-zero plot. Numerous magnitude errors, pass-band & stop band ripples decreases as order of digital filter increases, also stability increases with increasing order.

This paper is a review paper of all those researches which had been already developed. In section 2, IIR filter basic designing are discussed. In section 3, evolutionary techniques such as GA, PSO and their approaches are briefly described. In section 4, shows the literature survey part that what are those work which had done till yet. And the simulation, comparison of different outputs, coefficient, paretoo optimal solution and results with conclusion are mentioned in section 5.

II. IMPULSE-INFINITE RESPONSE

IIR (Recursive filter) is one of the two major types of digital filter. This filter is designed by existing method for designing analog filter. The IIR filter has feedback so it consists of past as well as present inputs and past output to create new output at every step. The IIR filter can be low-pass(LPF) filter, high-pass(HPF) filter, band-pass(BPF) filter, band-stop(BSF) filter with different orders. So the difference equation of IIR filter can be:

$$\sum_{i=0}^{L} b_i x(n-i) - \sum_{i=1}^{M} a_i y(n-i) \quad (1)$$

Basic filter is low-pass and have to achieve highpass and bandpass with the help of transformation or to achieve many stop and pass band by joining multiple filters with single pass band. To design IIR filter there are prototype analog family namely butterworth, chebyshev 1, chebyshev 2 and elliptic etc. IIR designed by bilinear transform is shown in figure below. The bilinear transform function is to convert the analog filter into the digital filter by fixing sampling frequency (fs). The transfer function of IIR (continuous) is given below:

$$\mathbf{H(z)}=\frac{Y(z)}{X(z)} = \frac{b_0+b_1z^{-1}+\cdots\ldots\ldots+b_Lz^{-L}}{1+a_1z^{-1}+\cdots\ldots\ldots+a_Mb^{-M}} \quad (2)$$

$$\mathbf{Or}\quad \mathbf{H}(e^{j\omega}) = \frac{b_0+b_1e^{-j\omega}+\cdots,+b_Le^{-j\omega L}}{1+a_1e^{-jw}+\cdots,+a_Me^{-jwM}},$$

$$\omega = \frac{2\pi f}{f_s}$$

2.1 Advantages:

- In terms of order they are very much efficient, they require low order.
- Poles-zero create efficiently for both notches and peak bands.
- Have recursive nature, Coefficients, Long impulse response with few feedbacks.
- It can achieve requires responses with less computational cost.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2015

2.2 Disadvantages:

- Stability is not confirmed always and feedback concern.
- Much more sensitive to finite word length implementation.
- Have non-linear phase, Quantization error
- Spectral notches are inefficient for all poles

2.3 Application:

- Telecommunication, data processing and Graphics
- image process, Speech, noise suppression or removing
- Radar, video and audio frequency signal

III. EVOLUTIONARY TECHNIQUES

There are number of evolutionary techniques out of which some are genetic algorithm, particle swarm optimization etc which proves very much helpful.

3.1 Why genetic algorithm is used to design IIR digital filter?

The designing of IIR filter by bilinear transformation require sufficient prior data to build up filter with desired parameter and show poor performance in maximum criteria. To overcome these unsolved problems we use optimization approach to solve most of the problem and provide more and more accuracy, high efficiency, achievement, less prior knowledge to design any digital IIR filter. Genetic algorithm work on the population of candidate's solution and various constraints under the strategy set before. It requires fitness function after which selection, crossover mutation and many process is performed [1,3]. Genetic optimization method comes up with new powerful approaches to solve the more difficult optimization problem.GA uses stochastic process and provide better solution or differently non-random solution. Genetic algorithm can be use for number of different application areas. Here is its flow chart in fig 1.

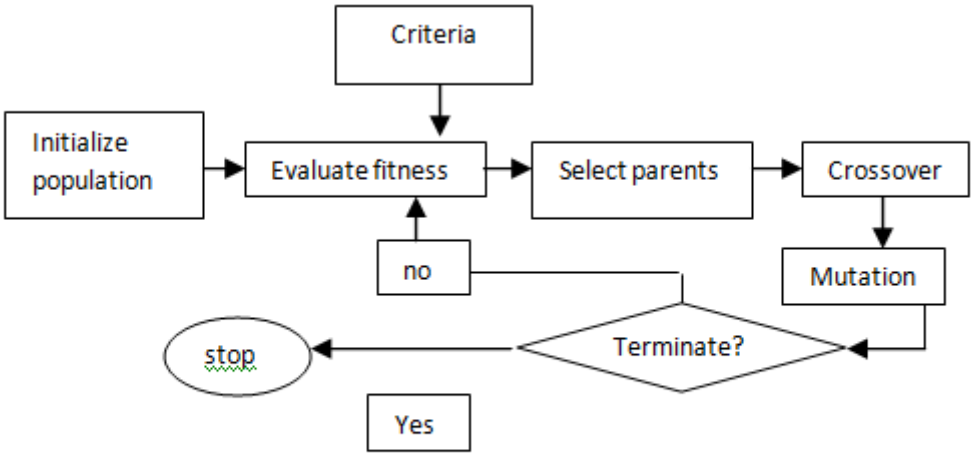

Figure1. Process of genetic algorithm

The multi-objective genetic algorithm is also very useful technique which is basically used when there is multi-objects and optimum solution have to determine. As objects are contradict of each other, in order to find paretoo optimum solution this technique is been used [4,6].

3.2 How particle swarm optimization (PSO) is helpful in designing filters?

Eberhart and Kennedy have developed a new computation technique PSO, in 1995 which is encouraged by the natural behavior of bird flocking and fish schooling. PSO is capable to solve non-differential function, larger space research

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2015

and also many aspects in engineering science. The PSO algorithm is different from genetic algorithm as PSO don't have operators like selection, crossover and mutation which genetic exist. It has great diversity and exploration on a single population also have faster convergence. PSO technique is much easy to implement and have less parameters to get adjust [5].

IV. LITERATURE REVIEW

Ranjit Singh, Sandeep K. Arya, Genetic Algorithm for the Design of Optimal IIR Digital Filters. In these optimum coefficients of IIR digital filter through GA is determined, and it is also found that the calculated values are more optimal than fda tool available to design filter in MATLAB. The simulation output of the applied modeled example shows an improvement on transition band and mean-square-error (MSE). The GAIIR produces filter coefficients that satisfy both magnitude and phase templates [1]. The fitness function of a solution in the population is determined by using fitness formulae given as:

$$\text{Fit(i)}=\frac{1}{k+J(w)i} \quad (3)$$

Many methods are carried out for IIR filters, which are used by numerous authors as a bench mark filter for comparing reason. They obtained magnitude response in which transition band is included, phase response in which result is identical to FDA tool. They designed pole-zero for low-pass filter and observed its location lies within unit circle, this proves that structured filter is stable. Then coefficients are compared with each other between FDA tool and SA method with minimum mean square- error (MSE).
Also the magnitude and phase response of high-pass filter is obtained by using FDA tool, SA and GA with the behavior of pole-zero and found it is also a stable filter. Now the coefficient of high pass filer is obtained with the evaluation of MSE and compared with traditional method resulting a proposed GA method gives far better solution and optimal coefficient of high-pass filter.

Abderrahmane Oudi, Hamid Bentarzi, " Optimal Multi-objective design of digital filters using Taguchi optimization technique". In this work, taguchi optimization technique is used to gain the design of multi-objective digital filter. Taguchi optimization is new approach in engineering field which found to be very effective in various implementations. The main object to use technique to reduce the time response, in spite of having minimum linear phase obtains desired frequency response[2].
The basic concept behind Taguchi's optimization is orthogonal array which is very easy to implement and to reach the desired parameters with great efficiency. Apart from this, the number of test required in optimization process is also low as compared to Genetic algorithm or PSO. Here filter is designed to pass band of frequencies within given interval and fixed sampling frequency with higher order and then compared with the SOS cascaded to match the desired magnitude response, minimum linear-phase and constant-delay to rise up the digital performance.

Ranjit kaur, manjeet patterh and J.S dhillon. "Real coded genetic algorithm for design of IIR Digital Filter with conflicting objectives". Multi-objective is considered in the designing of IIR digital filters using real-coded genetic algorithm (RCGA). Designed a digital filter after minimizing magnitude response and phase response which are two conflicting objects of the IIR digital filter acquire by using weighted sum approach.
The solution methodology follows initialization, reproduction, cross operators, mutation operators, competition and selection.
Finally this paper proposes RCGA method for optimizing the filter which has multiple conflicting parameters with each other. On the basis of obtained result for IIR filter by RCGA can be concluded as RCGA is robust algorithm which achieves the lowest order filter with better performance and output of magnitude and phase responses for all type of IIR filter. The result achieved for LP, BP, HP and BS filters by RCGA is being gathered and then comparison is done with HGA, CCGA, and LS-MOEA which attract the ones attention towards the better responses obtained by using RCGA[3].

Karan chhabra "design of digital filter by using multi-objective evolutionary algorithm". By designing a recursive filter whose function is to remove the undesired or unwanted frequency with help of GA and verify the effectiveness and

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2015

efficiency of MOEA on low pass (LP), high-pass (HP), band-pass (BP),band-stop(BS) Chebyshev filter. The filters can be analog or digital filters. The drawback of analog filter is its non-linear phase character, it is not a big problem but in some application it plays a big role such as telecomm, voice processing, image processing etc. the other drawback is less sharp cutoff frequency. So to overcome from all these limitations they design digital filters. Basically, most of the EA based IIR digital filter design work treat IIR filter by assuming single objective function with certain supplementary conditions, hence multiple objective has not focused and unable to obtain sufficient attention. So to consider both the parameters multi-objective evolutionary algorithm is used [4]. The objective function that is able to provide optimal response, stability and minimum-phase shown below.

$$\varphi(f) = e(f) + q_p w_p + q_z w_z \quad (4)$$

The fitness function used in this work is denoted by:

$$\text{Fitness} = \frac{1}{\varphi(f)} \quad (5)$$

So, in this paper with the help of MOEA Chebyshev filter with better efficiency and production cost is obtained for all type of filters. Also considered that IIR filter with higher linear characteristics and good stability when implementing with multi-objective GA other than conventional Algorithm[3].

Thus final result shows that the solution obtained for high-pass filter and low-pass by using fda tools is lesser approachable than the GA techniques. GA provides faster, more accurate, high performance and desired outputs. Moreover other evolutionary techniques can be used to design IIR filters.

Amandeep kaur maan, balraj singh, darshan S.sidhu, "Design of high order digital IIR using heuristic optimization technique". IIR digital filter of higher order is designed using nature inspired technique particle swarm optimization (PSO). PSO is applied to design the stable digital filter to avoid local minima, to enhance search capability, and to provide fast convergence. Then comparison is done between PSO and other designing technique and obtained that PSO gives better outputs then other [5]. The responses and stability is determined by taking help of MATLAB. Consequently, the stability function is found by designing pole-zero plots, and at last comparison has been made between different designing techniques with the PSO to demonstrate that it gives better and fine results than any other existing techniques in genetic algorithm field.

In this paper, the order of the filter is varies from 3 to 15 to get the different outcomes and to select the better one. The simulation results obtained by PSO are much better than that of RCGA and HTGA in form of magnitude error and ripple magnitudes in stop-band and pass-band. The finest result is obtained at 13^{th} order filter. So PSO algorithm consisting better performance in response, speed and stability of high order low pass digital filters.

Sonal Dwivedi " Designing of IIR filter with multi-objective genetic algorithm". This work is done by me in whom I have designed IIR low-pass digital filter of chebychev type. The order of the filter is low and has multi-objects which are conflicting to each other namely cut-off frequency and damping ratio. Addition to it, with the help of genetic algorithm a Paratoo optimal solution is found between the two conflicting objects by providing proper fitness function [6].

$$J_1(b_k, a_k) = -1/(w_d - w_p) \quad (6)$$

$$J_2(b_k, a_k) = -1/(\xi_d - \xi_p) \quad (7)$$

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2015

V. RESULTS & CONCLUSION

Filter design technique is now switching from traditional formula based design to intelligent design. We have seen lots of paper on the filter design using the Genetic algorithm and Particle swarm Optimization. These techniques as described and proved in discussed papers that they gives optimal result as compared to the traditional filter design techniques. The evolutionary algorithm required a fitness function which is to be minimized and the authors who uses genetic algorithm tried to develop a fitness function which gives better result. This is not guaranteed that Using these type of algorithm will gives better result than traditional method with every fitness function until we use proper fitness function. In this paper we discussed about the design of the IIR and FIR filters and how to design the fitness function for specific problems. The mathematical equation of the system with proper assumptions can increase the accuracy of the algorithm. We also discussed about the multi objective problem and find that the simplest way to use multi objective problem is to convert the multi objective problem into single objective problem by providing the weight to every objective according to its importance.

These algorithm are highly recommended for robotics with neural network called Hybrid intelligence. Using evolutionary techniques for optimizing the neuron weight can gives better result for particular network. Training algorithm for neural networks can be replaced by these algorithm. The most interesting fact of these algorithms are that they are inspired from the nature and we knows that nature is most optimum system we ever seen. Also the performance can be improved by modifying algorithm parameter.

REFERENCES

1.Ranjit singh, sandeep k. arya *" genetic algorithm for the design of optimal IIR digital filters*", journal of signal and information processing(JSIP), 2012,3,286-292.

2. Abderrahmane ouadi, hamid bantarzi, abdelmadjid recioui " *optimal multiobjective design of digital filters using taguchi optimization technique*", journal of electrical engineering, vol. 65, no.1, 2014, 21-29.

3. Ranjit kaur, manjeet singh patterh and J.S dhillon " *real coded genetic algorithm for design of IIR digital filter with conflicting objectives*", applied mathmetics & information sciences. 8, no. 5, 2635-2644(2014).

4. Karan chhabra*" design of digital IIR filter by using multi-objective evolutionary algorithm*", IRACST-ESTIJ, ISSN: 2250-3498.vol. 2, no. 2, april 2012.

5. Amandeep kaur maan, balraj singh, darshan s. sidhu" *design of high order digital IIR using heuristic optimization technique*", IJARCSSE, vol. 4, issue 10, October 2014.

6. Sonal dwivedi, pankaj shrivastav *" designing of IIR filter with multi-objective genetic algorithm*", IJMTER, vol. 3, issue 3, april 2015.

7. Er. Daljit singh bajwa, karamjeet singh, navpreet kaur chahal*" survey paper of digital IIR filter design*", IJARCSSE, vol. 4, issue 4, april 2014.

8. Abderrahmane ouadi" *optimal multi-objective design of digital filters using spiral optimization technique*", springer plus 2013,2:461.

9. Wei- der chang " *coefficient estimation of IIR filter by a multiple crossover genetic algorithm*", ELSEVIER (2006), 1437-1444.

10. Raaed faleh Hassan, ali subhi abbood" *design of finite impulse response filters based on genetic algorithm*", diyala journal of engineering sciences, vol. 06, no. 03, pp. 28-39, September 2013.

11. Pardeep kaur, simarpreet kaur*," to improve the magnitude response, phase variation and phase delay in FIR filters using GA*", IJAIEM, vo. 2, issue 1, January 2013.

12. Karaboga, Nurhan and Bahadir Cetinkaya, (2004), *"Performance comparison of Genetic Algorithm based design methods of digital filters with optimal magnitude response and minimum phase"*, IEEE. PP. 644-647.

13. Karaboga, Nurhan and Bahadir Cetinkaya, (2004), "*Optimal design of minimum phase digital FIR filters by using Genetic Algorithm*", IEEE. PP. 24-28.

14. Wade, *G.*, A. Roberts and *G.* Williams, (1994), "*Multiplier-less FIR filter design using a genetic algorithm*". IEE Proc.-Vis (Image Signal Process.), Vol. 141, No. 3, pp.175-180.

15. lngle, Vinay K. and John G. Proakis, (1997), "*DIGITAL SIGNALP ROCESSING USING MATLAB V.4*", PWS Publishing Company and International Thomson Publishing Inc.