Optimized Magnitude Response of IIR Filter using Genetic Algorithm

Deen Dayal Khandelwal[1] Vandana Vikas Thakare[2]
[1,2]Madhav Institute of Technology & Science, Gwalior

Abstract— In the proposed paper optimized magnitude response of low pass IIR filter is obtain by using genetic algorithm. Genetic Algorithm is a nature inspired optimization technique. The paper shows the magnitude response of the IIR filter obtain using the optimized filter coefficient. The experiment shows that the magnitude response obtain using optimized filter coefficient is more optimum compare to conventional techniques in terms of their cut off frequency.

Key words: Genetic Algorithm (GA), Infinite Impulse Response (IIR) Filter, Optimization, Filter Coefficient

I. INTRODUCTION

Digital filters are the most important tool in the field of signal processing. Due to number of advantages over analog filters. Digital filter finds application where high data rate is required. Infinite impulse response filter offer improved selectivity, computational efficiency and reduced system delay compare to Finite impulse response (FIR) filter [1].

Digital IIR filter follows two techniques transformation technique and optimization technique. Due to nonlinear and multimodal error surface of the IIR filters, conventional gradient based design methods stuck into the local minima problem. In order to tackle this problem efficient design methods which can achieve the global minima in a multimodal error surface are required [3]. Genetic algorithm is not only capable of searching multidimensional and multimodal spaces but also optimizes complex and discontinuous functions, the available optimization algorithm are based on the modern heuristics. Some of the optimization techniques are genetic algorithm (GA), Particle Swarn Optimization, Simulated Annealing (SA)[3], Hybrid taguchi genetic algorithm (HTGA) [4] and Immune Algorithm [5] etc.

In the proposed paper first the analog filter is transform into digital filter using bilinear transformation then the obtain filter coefficient is optimized using genetic Algorithm. Based on the optimized filter coefficient the magnitude plot and phase plot is plotted.

II. PROBLEM STATEMENT

To design an IIR filter firstly an analog filter is transformed into digital filter by using the transformation techniques. Some of the transformation techniques are impulse invariant method, matched Z transformation method and bilinear transformation (BLT). In the proposed filter Bilinear transformation is used because of its uniform mapping into Z plane. In bilinear transformation the analog filter into digital filter by replacing s with the equation 2.1 in the transfer function of the analog filter [6].

$$S=\frac{2}{T}\left(\frac{z-1}{z+1}\right) \qquad (2.1)$$

The recursive representation of IIR filter with input X (k) and output Y (k) is shown by equation 2.2 and the equivalent transfer function of an IIR filter is given by equation 2.3 [7].

$$Y(k)+\sum_{i=1}^{M} b_i\, y(k-i) = \sum_{i=0}^{L} a_i\, X(k-i) \qquad (2.2)$$

Where X (k) and Y (k) are the filter input and output respectively (M>L). M is the order of filter.

$$H(z) = \frac{A(z)}{B(z)} = \frac{\sum_{i=0}^{L} a_i\, z^{-i}}{1+\sum_{i=1}^{M} b_i\, z^{-i}} \qquad (2.3)$$

The parameter a_0, a_1 .....a_L; b_0, b1 .....b_M are called as filter coefficient. In addition, the above parameters are estimated by genetic algorithm so that the optimum value of the filter coefficient is optimized [8].

III. GENETIC ALGORITHM

The Genetic Algorithm is an example of a search procedure that uses a random choice as a tool to guide a highly exploitative search through a coding of a parameter space.

The principle and procedure of Genetic algorithm can be summarized under the following,

1) Outline of the Algorithm.
2) Initial population.
3) Creating the Next Generation.
4) Plots of Later Generation.
5) Stopping Condition for the Algorithm.

John Holland in the 60's AD presented the genetic algorithm with taking idea of the behaviour of chromosomes. Since it is a global optimization technique, it finds application in signal processing. The genetic algorithm approach in designing of IIR or adaptive filter is shown in the figure 1[9].

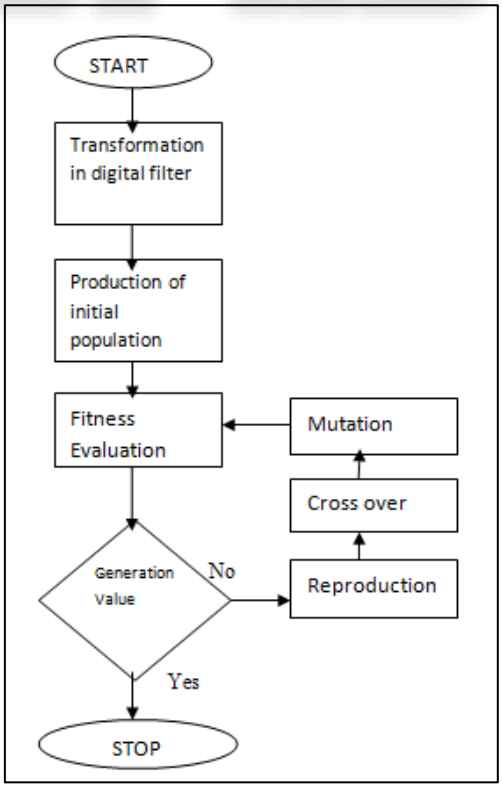

Fig. 1: Block Diagram of Filter Design

In the above block diagram following steps are taken in designing of the filter.

- Transformation of analog filter into Digital filter by using bilinear transformation.
- Population or a number of guesses for the solution of problem.
- A technique for calculating how good or bad the individual solution within the population.
- A way for mixing fragments of the better solution to form a newer one.
- A mutation technique or operator to avoid permanent loss of diversity within the solutions.

GA is a method for moving from one population of "chromosomes" (e.g., strings of ones and zeros, or "bits") to a new population by using a kind of "natural selection" together with the genetics−inspired operators of crossover, mutation, and inversion. Each chromosome consists of "genes" (e.g., bits), each gene being an instance of a particular "allele" (e.g., 0 or 1). The selection operator chooses those chromosomes in the population that will be allowed to reproduce, and on average the fitter chromosomes produce more offspring than the less fit ones [9]. Crossover exchanges subparts of two chromosomes, roughly mimicking biological recombination between two single−chromosome ("haploid") organisms; mutation randomly changes the allele values of some locations in the chromosome; and inversion reverses the order of a contiguous section of the chromosome, thus rearranging the order in which genes are arrayed. Genetic algorithm has the ability to tackle search spaces with many local optima that is one of the main reason involve in calculating the optimised filter coefficient in the proposed paper [10, 11].

IV. Fitness Function

The fitness function is the driving force behind the GA. It is called from the GA to determine the fitness of each solution string generated during the search. In the proposed paper, each solution string represent the optimum value of IIR filter coefficient based on the final optimum value of the filter coefficients the magnitude and phase plot is plotted. The fitness value of a solution in the population is calculated by using fitness function formula given as:

$$\text{fit (i)} = \frac{1}{m+J(w)i} \qquad (3)$$

Where J (w) is cost function and m is the number of poles outside the unit circle. The design of this filter can be considered as an optimization problem of cost function J (w) stated as follows

Min J (w)

Where w= [a0, a1 .....a_L; b_1,b_2 .....b_M] is the filter coefficient vector.

V. Result and Discussion

To show the result of genetic algorithm in the designing of digital filter an example is considered in which a low pass IIR filter of order 4 is considered. The initial population of chromosome is 100 and the length of chromosome is 10. The crossover and mutation probability is 0.8 and 0.1 respectively. After optimization of the filter coefficient the magnitude response of the IIR filter is shown in figure 2.

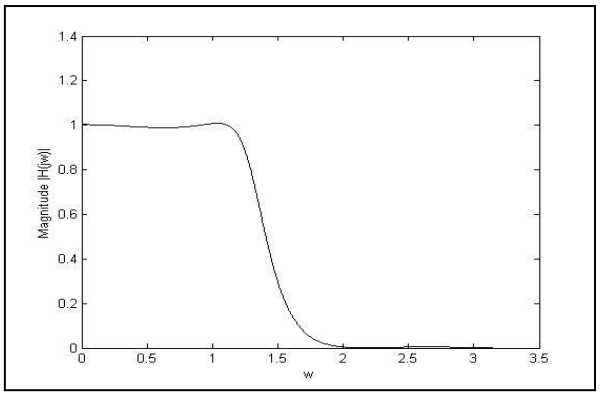

Fig. 2: Magnitude Response of GA Optimized IIR Filter.

The angular frequency is 1 rad/sec. is the cut off frequency in the proposed filter as shown in figure 2. A comparison graph between the magnitude responses of analog filter , scaled digital filter and GA optimized IIR filter is shown in figure 3.

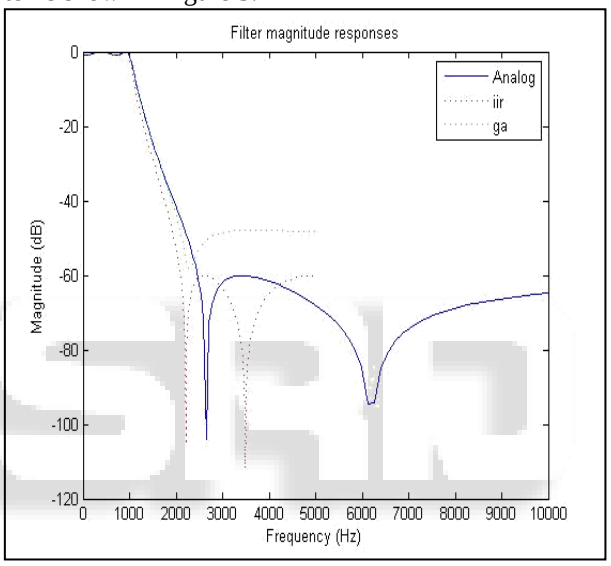

Fig. 3: Comparison Graph of Magnitude Response.

Figure 3 shows that the magnitude response obtains from optimized value of the coefficient is more optimum compare to normal filter in the term of cut off frequency.

VI. Conclusion

A genetic Algorithm approach has been proposed for the design of IIR digital filters. In the proposed algorithm, GA provides a very powerful option to tackle multimodal optimization problems, such as designing of IIR filter. As shown in the experimental result, the GA works well compare to conventional technique. Therefore, GA is a useful tool for the designing of IIR filter.

References

[1] A.V. Oppenheim, R.W. Schafer, J.R. Buck, Discrete-Time Signal Processing, Prentice Hall, NJ, Englewood Cliffs, 1999.

[2] J.H. Li and F.L. Yin, "Genetic optimization algorithm for designing IIR digital filters," Journal of China Institute of Communications China, Vol. 17, pp. 1–7, 1996.

[3] S. Chen, R. H. Istepanian, and B. L. Luk, "Digital IIR filter design using adaptive simulated annealing,"

Journal of Digital Signal Processing, Vol. 11, no. 3, pp. 241–251, July 2001.

[4] Jinn-Tsong Tsai, Jyh-Horng Chou and Tung-Kuan Liu, "Optimal design of digital IIR filters by using Hybrid Taguchi Genetic Algorithm" IEEE Transactions on Industrial Electronics, Vol. 53, No. 3, pp. 867–879, June 2006.

[5] Jinn-Tsong Tsai and Jyh-Horng Chou, "Optimal design of digital IIR filters by using an improved immune algorithm" IEEE Transactions on Signal Processing, Vol. 54, No. 12, pp. 4582–4596, December 2006.

[6] Andreas Antoniou, "Digital Filter Analysis, design and application" TATA McGRAW-HILL publication 2nd Edition.

[7] J. G. Proakis and D. G. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications," 3rd Edition, Pearson Education, Inc., New Delhi, 2007

[8] S.T. Tzeng and H.C. Leu, "complex genetic algorithm for designing equiripple complex FIR filter with weight function" signal processing 80, 197-204(2000)

[9] Melanie Mitchell, "An Introduction to Genetic Algorithm", MTT press book.

[10] S. Rajasekaran and G.A. Viayalakshmi Pai, "Neural network, Fuzzy Logic and Genetic Algorithm" PHI Learning Private Ltd, Delhi.

[11] Wei Der Chang "coefficient estimation of IIR filter by a multiple crossover genetic algorithm", science Direct published in August 2006

