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DETERMINING THE OPTIMUM COEFFICIENTS OF IIR ALL-PASS FILTER BASED ON GENETIC ALGORITHM

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Abstract: **The Digital Signal Processing (DSP) has a very strategic role nowadays in application fields like image processing, remote sensing, digital technology, and robotics. It becomes vital to estimate the type of response of a system. The function of filters is to extract meaningful knowledge from the signal or to eliminate the chosen vary of signal corresponding to noise. Proposed research work presents the technique of finding the optimum coefficients of IIR all-pass filter which is based on genetic algorithm. The ultimate aim is to find the objective function. It is achieved by minimising the error between the desired phase and the actual phase response. The evolutionary algorithm required a fitness function which is to be minimized and when the genetic algorithm is used we tried to develop a fitness function which gives a better result. The proposed methodology is validated and tested by the results of the simulation using MATLAB tool.**

Keywords *— All-pass ,Infinite Impulse Response (IIR), Genetic algorithm MATLAB tool.*

I INTRODUCTION

A filter is a device that is meant to pass frequencies inside a particular vary whereas rejecting all different unwanted frequencies that fall outside this vary. A Digital filters are a discrete-amplitude, linear time-invariant discrete time system. Linear Time-Invariant (LTI) filter is a type of filter whose output is a linear combination of the input signal samples and whose coefficients do not vary with time. In the time domain, the input-output relationship of a linear discrete-time filter is given by the following linear difference equation

$$y(m) = \sum_{k=1}^{N} a_k y(m-k) + \sum_{k=0}^{M} b_k x(m-k) \quad (1)$$

When a filter is implemented by convolution, each sample in the output is calculated by weighting the samples in the input and adding them together. A recursive filter is an extension of this, using previously calculated values from the output, besides points from the input. The recursive filter is formulated by the group of the recursion coefficients. The impulse responses of the recursive filter are composed of sinusoidal signals that are exponentially decaying in amplitude. In theory, the impulse response tends to infinite. However, the amplitude eventually drops below the round-off noise of the system, and the remaining samples can be ignored. Because of this characteristic, the recursive filter is also called Infinite Impulse Response (IIR) filter.

Yue-Dar Jour et al. have used a neural network-based architecture with the weighted least-squares technique to design IIR all-pass filter. The difference between the desired phase response and phase of the designed all-pass filter is to reflect the error and formulate it as a Lyapunov error criterion. The neural network achieves convergence to get the filter parameter by using the corresponding dynamic function. Further, weighted updating algorithm is introduced to achieve good performance with the minimum and maximum solution of the system. Weighted least square method is more used in research field because of the flexible use of the method of designing any type of filter [7].

Sunder S. kidambi studied the difference between the desired phase response and phase response of the practical all-pass filter can be formulated in a quadratic equation and which is reflected as the weighted error. They solved the linear system equation which includes teoplitz & Hankel matrix to find the coefficient of the filter and minimise the error. They introduced a weighted least-squares method to design all pass filter that has the least square or an equiripple phase error response. In the system of linear equation, the result minimization can be done by involving the teoplitz & Hankel matrix. The all-pass filter has many applications which involve notch filtering, complementary filter banks, multi-rate filtering and group delay equalisation [8].

Truong Q. Nguyen et al. designed all pass filter which is based on an eigenfilter algorithm for a given phase response. This approach is based on a formula which is in quadratic form and obtains the desired filter as an eigenvector which is real, symmetric, positive definite matrix. In the case of phase estimation,quadratic form error is not present because of the presence of the non-linear trigonometric functions. However, estimated least square phase error solutions can be constructed which gives an eigenfilter formula.The main reason for using the estimated linear IIR filter is that their phase responses are quite linear compared to the nonlinear phase responses of an elliptic filter, overall calculation and filtering delay is less than FIR filter [9].

Peng-Hua wang et al. have designed the maximally flat all pass fractional delay filter and fractional Hilbert transformers by using cepstrum-based approach. The cepstral coefficient is used to get the maximal fatness condition in the phase delay response. It is found that these coefficient are controlled by design parameter because of this simple. the non-complex methodology can be developed for the coefficient controlling phase shift delay. There is only need of one set and another group can be obtained by simple mathematical operation on the previous matrix of the coefficient [10].

S.C. Chan et al. have designed a causal-stable digital all-pass filter with the help of minimum & maximum design criteria by using second-order cone programming. SeDuMi toolbox is used to solving the problem of second-order cone programming. The total filter design issue can be explained by series of linear programming sub problem and bisection search algorithm. They have used another method which is imposing stability constraints and they have focused on nonlinear constraints such as pole radius constraints of the filter which can be solved by using Rouche's theorem. Pole radius constraints allow an excess trade off between estimate error and stability margin. When pole radius is satisfied then required solution is obtained for a given ripple [11].

II PROPOSED METHODOLOGY

Genetic Algorithm (GA) is a search – based optimisation technique, which is based on the principles of Genetics and Natural Selection. Genetic Algorithm is a type of optimisation algorithm, meaning they are used to find the optimal solutions to a given computational problem that maximizes or minimizes a particular function. Since genetic algorithms are designed to simulate a biological process, much of the relevant terminology is borrowed from biology.

The proposed method utilises Genetic Algorithm technique to determine the optimum coefficients of a filter to realise the objective function which is minimizing the error between the desired phase and the actual response. The cycle of the Genetic Algorithm process is depicted in the figure below.

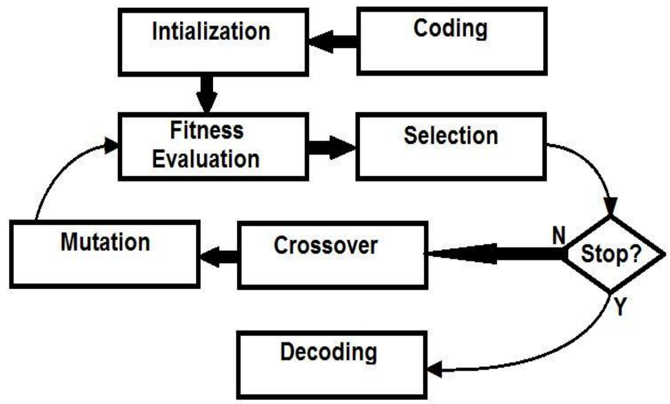

Figure 1 Flow diagram of Genetic Algorithm

Initially, populations of the filter coefficients are generated with the lower and upper bands and the objective function is applied every cycle and the most fitted populations were selected and the others are discarded. The selected population besides the populations comes from the mutation and the cross over operator is passed as the input to the next cycle and so on until one of the termination conditions is realized. Termination conditions were used dare the stall time, or the best fitness limit, or the maximum number of iterations [1].

The objective function that has been used,

$$e_{min} = \emptyset_{des} - \emptyset_A \qquad (2)$$

III VALIDATION

In this work, MATLAB version R2013a software, the hardware specification of PC is Intel core i3-5005U CPU @2.00GHz,8GB RAM is used to simulate IIR all-pass filter having the specifications as those of [12][13] for evaluating the performance of the Genetic algorithm technique. The initial filter coefficient is set as $a_n(0) = 10^{-4}, n = 0,1,2,\cdots, N$, step size $\mu = 0.005$ and termination condition $\varepsilon = 10^{-10}$. The frequency sampling grid is set to $L = 10N$ for all of the following examples.

Example: A Hilbert transformer with filter length $N = 4$ and group delay $D = 5$ is designed using IIR all-pass filter. The desired phase response is given by

$$\varphi_H(\omega) = -D\omega - \pi/2, \quad .06\pi \le \omega \le 0.94\pi$$

It took 201 iterations to reach the desired accuracy by using neural learning algorithm. The value of peak group delay of the neural learning algorithm is -0.9543. The designed phase response when the convergence takes place as shown in figure 2. As seen from figure 2, the design error phase response is displayed.

For the higher order sinusoidal group delay all-pass filter having a desired phase response is designed by

$$\varphi_A(\omega) = 4\pi[\cos(\omega) - 1] - 52\omega.$$

It is proposed to determine the optimum coefficients of the filter to realize the objective function which is minimizing the error between the desired phase and the actual phase response is given by the following equation:

$$e_{min} = \varphi_{des} - \varphi_A$$

By comparing the results of the proposed work (Based on Genetic Algorithm) with the results obtained by considering same parameters as used in the reference work, which is based on neural network. In order to validate and verify the results, we compared the graph between magnitude response, phase response, and group delay response to the normalized frequency of the neural learning algorithm and proposed genetic algorithm. We also compared the optimum coefficients of the neural learning algorithm and proposed genetic algorithm as tabulated in table 1. The value of peak group delay of the genetic algorithm is 0.0214.

IV RESULTS & DISCUSSION

1. When the convergence takes place then the graph of the phase response and the phase error response is displayed. The neural learning algorithm based graph is obtained in Figure

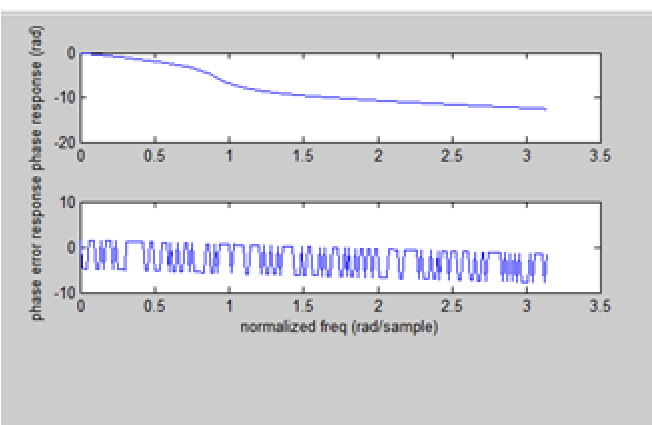

Figure 2

2. The neural learning algorithm based graph is displayed in Figure 3. The magnitude response is constant in figure 3. The designed phase response approaches closely to the desired phase response and achieves approaches closely the group delay as compared the desired group delay.

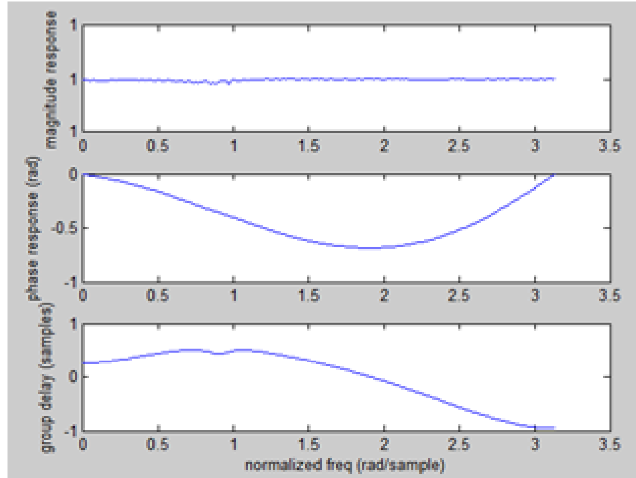

Figure 3

3. The Genetic algorithm based graph is displayed in figure 4. The design phase response and peak error response are displayed in Figure 4.

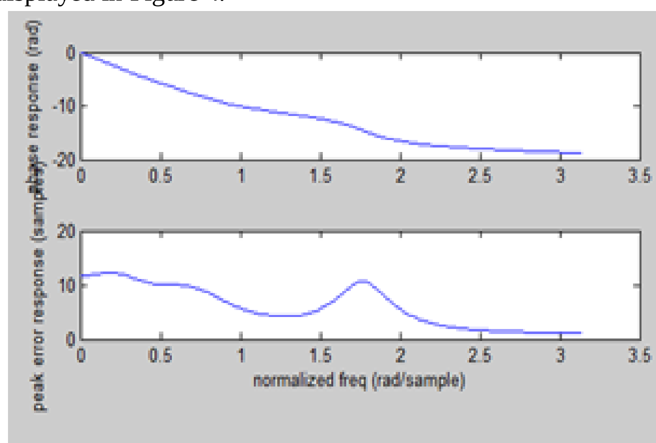

Figure 4

4. The Genetic algorithm based graph is displayed in Figure 5. The magnitude response is also constant. The designed phase response approaches closely to the desired phase response and achieves approaches closely the group delay as compared the desired group delay.

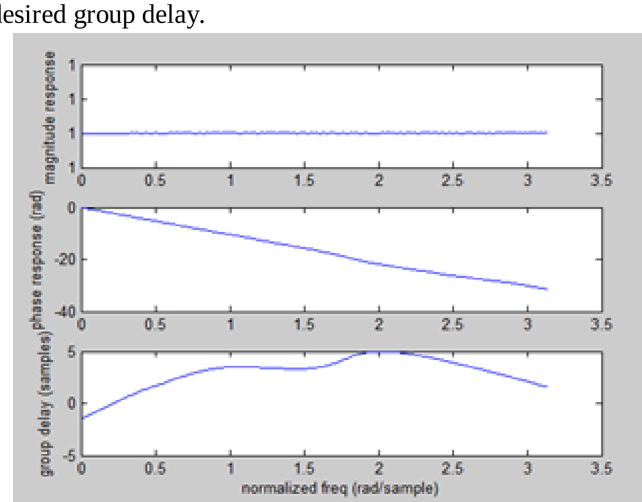

Figure 5

5. The Genetic algorithm results accuracy is based on the database, as much the initial population as much the accuracy of the result. The convergence time for the Genetic algorithm based methods is faster. In Convergence time as it is not based on calculation, it is based on searching the database which may include results of the based code so it is more accurate and faster.

Table 1: Optimum Coefficients

Index	Neural Learning Algorithm	Proposed Genetic Algorithm
0	0.0596	0.4780
1	-0.0424	0.1318
2	-0.5216	-0.0498
3	0.8181	1.6090
4	-0.7224	-1.7079

V CONCLUSION

Present research work introduces a proposed Genetic Algorithm search - based technique to design IIR all-pass filter by deciding the optimum filter coefficients for realizing the minimum error between the actual and desired phase response. A complete graphical user interface is implemented including the basic technique which is based on neural network and the proposed technique based on GA. The results are compared and validated. The results show that the proposed technique has lower time convergence and higher accuracy with lower error than the basic neural learning algorithm.

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