Survey on FIR Digital Filter Design

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Abstract—FIR filters are known to have many desirable features such as guaranteed stability and linear phase characteristics at all frequencies. Various techniques have been used in the past to design the filter for removing noise and achieving exact frequency response with high stop band attenuation and low stop band and pass band ripples. The paper presents the review of various such optimization techniques that have been used in the past for getting the exact frequency response of FIR filter.

Keywords—Finite Impulse Response, Infinite Impulse Response, Genetic Algorithm, Particle Swarm Optimization, Craziness based Particle Swarm Optimization Technique.

I. INTRODUCTION

In recent years, FIR digital filters has gained much popularity due to the convenience and flexibility with which it can be used. But the design of filter for removing noise and achieving exact frequency response with high stop band attenuation and low stop band and pass band ripples also become important at the same time. Various techniques that have been used in the past for this purpose have been discussed in the section II and the conclusion of the review has been given in section III, thus summarizing the whole discussion.

II. LITERATURE SURVEY

L. LITWIN mentioned the concept of digital filter in 2000 [1] as simply a discrete time, discrete amplitude convolver. Digital filters are basic building blocks in many digital signal processing systems. They have wide range of applications in communication, image processing, pattern recognition, etc. There are two major types of digital filters, that is, finite impulse response (FIR) filters and infinite impulse response (IIR) filters depending on the length of the impulse response. The general difference equation for FIR filter is

$$\boldsymbol{y(n)} = \sum_{\boldsymbol{k=0}}^{\boldsymbol{k=M-1}} \boldsymbol{b_k x(n-k)}$$

where y(n) is the filter output at discrete time instance n, bk is the k-thfeedforward tap, or filter coefficient and x(n-k) is the filter input delayed by k samples. M is the number of feedforward taps in the FIR filter.

LAWRENCE R. RABINER in April 1971[2] discussed several techniques including windows method, frequency sampling method and equiripple designs for designing FIR filters. With the help of these techniques and filter characteristics, ease of design and methods of realization have been compared. Difficulty in calculation of Bessel function and Fourier series coefficient was the major disadvantage in window method technique. But transition bandwidth in the case of Frequency Sampling technique has been found to be 3/4th to that of Kaiser window whileEquiripple design had smallest transition bandwidth. But if the ease of design parameter is considered, window method tends to be relatively easy to be used. The choice of technique depends heavily on the decision, whether to compromise accuracy of approximation or ease of design.

THOMAS w. PARKS and JAMES H. MCCLELLANin march 1972[3]presented Chebyshev Approximation method for the design of linear phase FIR filter, especially for the very long filters. In the cases discussed, the number of iterations never exceeded 10 and was usually about 6 or 7. A filter of length 95 was designed in 200 seconds with 10 iterations. With the help of this technique, the exact specification of the band-edge frequencies was obtained, whereas previous procedures obtained the band edge indirectly. Several graphs were included to show relations among the parameters of filter length, transition width, bond-edge frequencies, passband ripple, and stopbond attenuation. A limitation of this procedure was that it was not possible to specify all of the desired parameters independently.

A. LEE, M. AHMADI *et al*designed FIR filter using Genetic Algorithm (GA) in 1999[4] for obtaining optimal solutions which attracted most of the attention. Filters with binary, integer or real coefficients could be easily handled by the proposed method. The genetic algorithm comprised of three genetic operations, namely reproduction, crossover and mutation. These three operations were applied again and again and through natural selection and genetic operators, mutation and recombination, chromosomes with better fitness were found. Natural selection guaranteed that chromosomes with the best fitness would propagate in the future populations. It was tested for the design of filters with different amplitude and phase specifications.

SABAH M. AHMED used the design technique that was implemented using Matlab in a form of interactive toolbox for FIR filter design using GAin 2004[5]. Simulation results for the filter design using GA were compared ,and it was found that GA gave us the exact cut off frequency. Also the ripples in the pass band and in the stop band regions were attenuated successfully, but the problem was that the GA was inefficient in determining the global optimum in terms of convergence speed and solution quality.

In order to overcome the problems associated with RGA, Particle Swarm Optimization (PSO) was developed by JEHAD I. ABADNEH and MOHAMMAD H. BATAINEHin june 2007[6]. The PSO was able to solve multidimensional optimization problems. It was based on simulating the social behaviour of swarm of bird flocking, bees, and fish schooling.PSO was initialized by group of random particles (solutions) and then searches for optima by updating generations. PSO was found to be ease of implementation in both the context of coding and parameter selection. This algorithm was much simpler as compared to GA. Also, results showed that the PSO outperformed the GA. Many algorithms showed the problems of premature convergence, stagnation and revisiting of the same solution over and again.So to maintain the diversity of the particles ,a new velocity expression was introduced named "craziness velocity" having a predefined probability of craziness.

SANGEETA MANDAL *et al.* used Craziness based Particle Swarm Optimization Technique (CRPSO)[8],[9],[12], in 2012, 2015. CRPSO technique tried to find the best coefficients that closely match the ideal frequency response. A novel Craziness based Particle Swarm Optimization (CRPSO) technique was applied to the solution of the constrained, multimodal, non-differentiable, and highly nonlinear FIR band stop filter design problem to obtain the optimal filter coefficients. With almost same level of the transition width, the CRPSO produced the highest stop band attenuation and the lowest stop band and the pass band ripples as compared to those of PM algorithm, RGA and conventional PSO. Results obtained showed that the CRPSO did not show the problem of premature convergence .Then same technique was applied to FIR high pass filter and FIR low pass filter by SANGEETA MANDAL *et al.,*[8], [9] to obtain better results in comparison to genetic algorithm. This technique outperformed in the optimal characteristics of frequency spectrums.

Table 1. Comparisonof different optimization algorithms for FIR digital filter design.

Sr no	Title	Journal/ Conference	Author & Year	Findings	Weakness
1	FIR and IIR digital filters	IEEE	L. Litwin, 2000	Concept of digital filters.	------------------
2		IEEE	L. R. Rabiner,	Easy to design	

	Techniques for designing finite-duration impulse response digital filters		1971		Difficulty in calculation
3	Chebyshev approximation for non recursive digital filters with linear phase	IEEE	T.W. Parks, J.H. McClellan, 1972	Exact specification of the band-edge frequency	Increased computational cost
4	Design of 1-D FIR Filters with Genetic Algorithms	IEEE	A. Lee, M. Ahmadi, *et al.,* 1999	Ripples attenuated	Determining the global optimum
5	Design Of FIR Filters With Arbitrary Amplitude And Phase Specifications Using Genetic Algorithm	IEEE	Sabah M. Ahmed 2004	Guaranteed best fitness	Speed (45 minutes)
6	Linear phase FIR filter design using particle swarm optimization and genetic algorithms	Elsvier	J.I. Ababneh, 2008	High speed	Premature convergence
7	Craziness based Particle Swarm Optimization algorithm for FIR band stop filter, low pass, high pass filter design	Elsvier , IEEE	D. Mandal, *et al.,*2012 Borah, *et al.,*2015	Low ripples high stop band attenuation	computationally costlier

III. CONCLUSION

Different techniques have been discussed by the authors to get the exact frequency response of FIR filter by making use of various optimization algorithms like chebyshev, GA, PSO etc. to produce the highest stop band attenuation and the lowest stop band and the pass band ripples. Filters were so developed so as to obtain better results with previously developed methods and algorithms. The literature review findings have solidified our idea of using the optimization filter for the quality improvement and the signal size reduction. In this paper, we are giving the idea of using the adaptive optimization methods to design the optimal FIR filter. The new filter is aimed to use the grey wolf optimizer for the purpose of optimization based FIR filter design. The proposed scheme is aimed at solving the existing issues of signal quality, elapsed time, signal similarity, etc. The quality parameters of peak signal to noise ratio and mean squared error would be used to evaluate the performance of the proposed model in order to evaluate its quality against the existing optimization based FIR filters.

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