A Low Pass FIR Filter Design Using Particle Swarm Optimization Based Artificial Neural Network

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Abstract: For the design of low pass FIR filters complex calculations are required to calculate the filter coefficients. Mathematically, by substituting the values of pass band, transition width, pass band ripple, stop band attenuation and sampling frequency in any of the methods like window method, frequency sampling method or optimal method we can get the values of filter coefficients h(n).

In this paper a low pass FIR filter has been designed using artificial neural network. The optimization of the network has been done using particle swarm optimization algorithms. The proposed approach has been compared with Kaiser window method. The result shows that the filter designed using ANN optimized with PSO requires lesser iterations for the performance goal meeting.

Keywords: FIR Filter, Kaiser window, ANN, PSO

1. INTRODUCTION

With the technological evolution, great advances have been made on design techniques for various digital filters. A filter is essentially a system or network that selectively changes the wave shape amplitude -frequency and or phase – frequency characteristics of a signal in a desired manner. A digital filter is a mathematical algorithm implemented in hardware and/or software that operates on a digital input signal to produce a digital output signal for the purpose of achieving a filtering objective. A simplified block diagram of a real-time digital filter, with analog input and output signals is given in Fig.1.

Fig.1: Block diagram of digital filter.

2. FIR FILTER DESIGN

The design of a digital filter involves five steps:

(1) Filter Specification: This may include stating the type of filter, for example low pass filter, the desired amplitude and/or phase response and the tolerances (if any) we are prepared to accept, the sampling frequency and the word length of the input data.

(2) Coefficient calculation: At this step, we determine the coefficients of transfer function, H(z), which will satisfy the specifications given in 1. Our choice of coefficient calculation method will be influenced by several factors, the most important of which are the critical requirement in step 1

(3) Realization: This involves converting the transfer function obtained in 2 into suitable filter network or structure.

(4) Analysis of finite word length effects: Here, we analyze the effects of quantizing the filters coefficients and input data as well as the effect of carrying out the filtering operation using fixed word lengths on the filter performance.

(5) Implementation: This involves producing the software code and/or hardware and performing the actual filtering. The criteria is a linear phase response in frequency domain called phase response (Jin et al., 2006) as shown in figure. Finally, because there is a tradeoff between filter complexity and implementation feasibility, complexity and implementation feasibility, complexity is a performance criteria. Ideal filter characteristics are practically unrealizable. There are many methods to design FIR filter which are:-

(1) Fourier series method
(2) Frequency Sampling method
(3) Window method

The most of these design techniques suffer from some kinds of drawback. Some of them could not give optimal design in any sense, some is lacking of generality, some need long computing time, and so on (Bagachi and Mitra, 1996). Kaiser window method has been used because of the presence of ripple parameter beta.
Kaiser determined empirically that the value of $\beta$ need to achieve a specified value of $A$ is given by

$$
\beta = \begin{cases} 
0.1102(A - 8.7) & \text{for } A > 50 \\
0.5842(A - 21)^{0.8} + 0.07886(A - 21) & \text{for } 21 \leq A \leq 50 \\
0 & \text{for } A < 21
\end{cases}
$$

The case $\beta = 0$ is the rectangular window for which $A = 21$.

Furthermore, to achieve prescribed values of $A$ and $df$, $M$ must satisfy equations:

$$
M = \begin{cases} 
\frac{A - 8}{14.36df} + 1 & \text{for } A > 21 \\
(0.922 / df) + 1 & \text{for } A \leq 21
\end{cases}
$$

Finite Impulse response filters (Öner and paper., 1999) are preferred for their stable and linear phase characteristics. But due to long impulse response of FIR filters there will be more hardware complexity. The design of digital filter means basically finding the values of filter coefficients so that given filter specification are achieved the window based design method are exclusively used for calculating there coefficient. In this paper Kaiser window is used for this purpose. ANNs have been used for the design of digital filter with pass band edge frequency, transition width, pass band ripple, stopband attenuation, sampling frequency as input parameters. In this paper a low pass FIR filter has been designed using artificial neural network. The optimization of the network has been done using particle swarm optimization. PSO is less susceptible to getting trapped on local optima unlike GA. The network has been trained in such a manner so that the error reduces to minimum. The objectives of the present work are divided into the following sections.

1. To prepare the data sheet using different values of filter parameter achieve the filter coefficient.
2. Using ANN a low pass FIR filter has been designed with PSO as the optimization tool, such that its coefficient match with coefficients obtained with window method.

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<thead>
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<th>$h(n)$</th>
<th>Kaiser Window Method</th>
<th>Artificial Neural Network</th>
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<td>$h(0)$</td>
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<td>$h(12)$</td>
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</tbody>
</table>

4. RESULTS

The network has been trained using Multilayer Perceptron in which Error Back Propagation Algorithm has been specifically used to design Low Pass FIR filter.

4.1 KAISER VS ARTIFICIAL NEURAL NETWORK

Input parameters: Transition width=50Hz, Sampling frequency=2.5kHz.
Frequency=1KHz, Pass band Ripple=0.1dB, Filter Length=3, Passband=150Hz, Stopband Attenuation = 10.1040dB.

The Input Data Set taken is $TW = 52$, $SF = 1.3$, $PBR = 0.12$, $N=4$, $PBF=151$, $SBT=9.9413$. The ANN has been optimized using PSO. The results obtained are shown in Fig. 5, 6, 7 & 8.

5. CONCLUSION
The present work has illustrated the use of artificial
neural network for the design of low pass FIR filters using PSO rather than using the complex calculative Window method.

Artificial Neural Network is better and easy method for the design of low Pass FIR Filter. Using Fourier series, frequency sampling or window methods the filter can be designed but for each unknown parameter the filter coefficients have to calculated. In comparison with ANN, the trained network can calculate the filter Coefficient for unknown parameter in that specified range. The ANN optimized with PSO is meeting the performance goal in just 8 iterations.

REFERENCES


