Design of Optimal Digital FIR Filter Using Particle Swarm Optimization Algorithm

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Abstract. Designing a good performance FIR filter is a core problem in signal processing field over the years in determining the sample value in the transition zone. Obviously, Genetic Algorithm method cannot guarantee that interpolator is the optimal sampling point. This method is complex in structure which takes longer time in operation & suffers from local optimal solutions. In this paper PSO method is used to determine the frequency response of Digital FIR low pass filter, consequently the optimal filter coefficients are obtained with fast convergence speed and also error function is minimized, when compared with the errors obtained from windowing techniques. PSO algorithm is implemented in FIR filter in an efficient way to improve the stop band attenuation such that the samples are interpolated near the discontinuity and reduce errors. The performance of this PSO is compared with the conventional window techniques have been verified via computer simulations using Matlab.

Keywords: PSO, LMS Error, Filter Ripples, Windowing Methods, Swarm.

1 Introduction

Particle Swarm Optimization is a population based stochastic optimization technique developed by Dr.Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling[1]. In PSO the potential solutions, called particles, fly through the problem space by following the current optimum particles [3]. Each particle keeps track of its coordinates in the problem space which are associated with best solutions (fitness) it has achieved so far. This value is called pbest. When a particle takes all the population as its topological neighbors. The best value is called global best (gbest). The particle swarm optimization concepts consist of, at each time step, changing the velocity of each particle towards its pbest location. PSO has no potential evolution operators such as crossover and mutation[7].

2 Quantitative Analysis of PSO and Fir Low Pass Filter

The frequency response of a linear-phase FIR filter is given by

$$H(\omega) = \sum_{i=1}^{k} h(n)e^{-j\omega n}$$  \hspace{1cm} (1)
Where \( h(n) \) is the real valued impulse response of filter, \( N+1 \) is the length of filter and \( \omega \) is frequency according to the length being even and odd and the symmetry being an even and odd four types of FIR filters described.

The linear phase is possible if the impulse response \( h(n) \) is either symmetric (i.e. \( h(n) = h(N-n) \)) or is anti symmetry \( h(n) = -h(N-m) \) for \( 0<=n<=N \).

In general the frequency response [5] for type 1 FIR filter can be expressed in the form

\[
H(e^{j\omega}) = e^{-jn\omega/2} \tilde{H}
\]  

(2)

Where amplitude response \( \tilde{H}(\omega) \), also called the zero response, is given by

\[
\tilde{H}(\omega) = h(N/2) + \sum_{n=1}^{N/2} h(N/2-n) \cos(\omega n)
\]  

(3)

The amplitude response for the type 1 linear phase FIR filter [5] (using the notation \( N=2M \)) is expressed as

\[
\tilde{H} = \sum_{k=0}^{M} a(k) \cos(\omega k)
\]

Where \( a(0)=h(M) \) and \( a(k)=2h(M-k), 1<=k<M \)

The amplitude response for the type 2 linear phase FIR filter is given as

\[
A(\omega) = \sum_{i=1}^{k} \left[ W(\omega) \left[ \sum_{k=0}^{M} a(k) \cos(\omega k) - D(\omega_i) \right] \right] \cos(\omega k - 1/2)
\]

\[
A(\omega) = \sum_{k=1}^{2M+1/2} b(k) \cos(\omega k - 1/2)
\]

Where \( b(k)=2h[2m+1/2-K], 1<K<2M+1/2 \)

The amplitude response for the case of type 3 linear phase FIR filter is given as

\[
A(\omega) = \sum_{k=1}^{M} c(k) \sin(\omega k)
\]

Where \( c(k) = 2h(M-k), 1<=k<=M \)

The amplitude response for the case of type 4 linear phase FIR filter is given as

\[
\tilde{H}(\omega) = \sum_{k=1}^{2M+1/2} d(k) \sin(\omega k - 1/2)
\]

Where \( d(k)=2h[2M+1/2-K], 1<=k<=2M+1/2 \)

The design of a linear phase FIR filter with least mean square error criterion, we find the filter coefficients \( a(k) \) such that error is minimized. Corresponding to the coefficients the filter coefficients are obtained as shown by the equations.