Chapter 17
Design of Linear Phase FIR Low Pass Filter Using Mutation-Based Particle Swarm Optimization Technique

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ABSTRACT

This chapter presents a mutation-based particle swarm optimization (PSO) approach for designing a linear phase digital low pass FIR filter (LPF). Since conventional gradient-based methods are susceptible to being trapped in local optima, the stochastic search methods have proven to be effective in a multi-dimensional non-linear environment. In this chapter, LPF with 20 coefficients has been designed. Since filter design is a multidimensional optimization problem, the concept of mutation helps in maintaining diversity in the swarm population and thereby efficiently controlling the local search and convergence to the global optimum solution. Given the filter specifications to be realized, the Mutation PSO (MPSO) tries to meet the ideal frequency response characteristics by generating an optimal set of filter coefficients. The simulation results have been compared with basic PSO and state of artworks on filter design. The results justify that the proposed technique outperforms not only in convergence speed but also in the quality of the solution obtained.

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INTRODUCTION

Digital filters are more preferred nowadays because they exhibit higher performance in terms of attenuation along with lower equipment production cost than analog filters. Analog filters use electronic components such as resistors, capacitors, and transistors to perform filtering operations. It finds applications in areas where noise reduction and improvement in the signal properties are required. A digital filter, on the other hand, is a frequency selective device that allows a certain frequency to pass through it while attenuating all other undesired frequencies including the noise signals. It performs calculations on the sampled values of the signal.

Traditionally different techniques exist for the design of digital filters; they are namely window method, frequency sampling method, and the Parks–McClellan (PM) algorithm(Parks & McClellan, 1972b)(Parks & McClellan, 1972a)(James McClellan & Parks, 1973)(J McClellan, Parks, & Rabiner, 1973)(L. R. Rabiner, 1972)(L. Rabiner, 1972). The conventional window method of digital filter design involves multiplying the ideal impulse response with some window function. The window function could be Butterworth, Chebyshev, Kaiser, etc., depending upon passband and stopband ripples, stopband attenuation, and transition width. Although the different windows limit the infinite length impulse response to a finite one they do not allow sufficient control over different filter parameters like transition width and the frequency response in various frequency bands(Oppenheim, 1999). The frequency sampling method is commonly used when the recursive and non-recursive implementations of FIR filter is required.

In PM algorithm filter length (M), passband and stopband normalized frequencies (ωp, ωs), and the ratio of a maximum of the absolute ripple in the passband and stopband (δp,δs) are fixed. However, the PM algorithm does not permit explicit selection of δp and δs, instead one can only specify them in terms of their ratio. Furthermore, the PM gives floating-point coefficients which require quantization. The limitations of the conventional window and PM algorithm stated above motivates us to use the computational intelligence techniques like PSO for digital filter design to have better parameter control and better approximation to the ideal filter. Additionally, all the constraints of filter design can be effectively taken care of by the use of CI techniques as they have proven to be effective in the multidimensional nonlinear environment (Kennedy & Eberhart, 1995) (Boeringer & Werner, 2004).

BACKGROUND

Optimum FIR digital filter design using computational intelligence based optimization algorithm is described in (Teixeira & Romariz, 2007) (Flavio, 2007). A comparison of the Genetic Algorithm (GA) and PSO techniques for the design of the FIR filter are described in works by (Najjarzadeh & Ayatollahi, 2008)(Ababneh & Bataineh, 2008). The authors have indicated PSO to be a better performer. Differential evolution PSO(DEPSO) for the design of digital FIR filter design is described in (Luitel & Venayagamoorthy, 2008)(Reddy & Sahoo, 2015). PSO with constriction and time-varying inertia weight for the design of the high pass filter is described in (Kar, Mandal, & Ghoshal, 2011). Improved PSO for the