A Novel Firefly Algorithm for Optimal Linear Phase FIR Filter Design

Suman Kumar Saha, Department of Electronics and Communication Engineering, National Institute of Technology, Durgapur, India

R. Kar, Department of Electronics and Communication Engineering, National Institute of Technology, Durgapur, India

D. Mandal, Department of Electronics and Communication Engineering, National Institute of Technology, Durgapur, India

S. P. Ghoshal, Department of Electrical Engineering, National Institute of Technology, Durgapur, India

ABSTRACT

Optimal digital filter design in digital signal processing has thrown a growing influence on communication systems. FIR filter design involves multi-parameter optimization, on which the existing optimization algorithms do not work efficiently. For which different optimization techniques can be utilized to determine the impulse response coefficient of a filter and try to meet the ideal frequency response characteristics. In this paper, FIR low pass, high pass, band pass and band stop filters have been designed using a new meta-heuristic search method, called firefly algorithm. Firefly Algorithm is inspired by the flash pattern and characteristics of fireflies. The performance of the designed filters has been compared with that obtained by real coded genetic algorithm (RGA), standard PSO and differential evolution (DE) optimization techniques. Differential evolution (DE) is already one of the most powerful stochastic real-parameter optimization algorithms in current use. Here the firefly algorithm (FA) technique has proven a significant advantage. For the problem at hand, the simulation of designing FIR filters has been done and the simulation results demonstrate that Firefly algorithm is better than other relevant algorithms, not only in the convergence speed but also in the performance of the designed filter.

Keywords: Convergence, Differential Evolution (DE), Evolutionary Optimization Technique, Finite Impulse Response Filters (FIR Filter), Firefly (FF), Magnitude Response, Particle Swarm Optimization (PSO), Real Coded Genetic Algorithm (RGA)

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INTRODUCTION

According to the characteristics of impulse response, digital linear filters are of two types; Finite impulse response (FIR) filters and infinite impulse response (IIR) filters (Oppenheim, Schafer, & Buck, 1999). In FIR filter design the impulse response is windowed by different windowing functions to implement filters of varying characteristics, whereas in IIR filter design the filter coefficient values are required for implementation (Parks & Burrus, 1987; Rabiner, 1973; Herrmann & Schussler, 1970). The filter output is simply a delayed and amplitude-scaled version of the input signal. The choice of FIR and IIR filters depends on their relative advantages. Normally IIR filters have sharp cut-off and high throughput and its implementation involves fewer parameters. Thus computational complexity is less. However, the main advantages of FIR filters are that they are always stable unlike IIR filters and least susceptible to round-off arithmetic errors as can occur in some shorter IIR filters. More importantly, phase linearity is guaranteed in FIR filters, thereby, avoiding signal distortion. They can be designed to serve as time varying filters also by changing the sampling frequency and by changing the coefficients as functions of time, namely, by changing the algorithm (Parks & McClellan, 1972; McClellan, Parks, & Rabiner, 1973) accordingly. The frequency sampling (FS) technique has the advantages that more effective narrow band filters can be designed with arbitrary responses. However, these techniques do not have a sufficient control over the transition band frequency sample values and result in suboptimal solutions. Different heuristic optimization techniques are reported in the literatures. When considering global optimization methods for digital filter design, GA (Lee, Ahmadi, Jullien, Miller, & Lashkari, 1998; Ahmad & Antoniou, 2006; Mastorakis, Gonos, & Swamy, 2003; Lu & Tzeng, 2000), orthogonal genetic algorithm (OGA) (Ahmad & Andreas, 2006), hybrid Taguchi GA (TGA) (Tang & Shen, 2010), Tabu search (Karaboga, Horrocks, Karaboga, & Kalinli, 1997), Simulated Annealing (SA) (Chen, 2000), Bee Colony Algorithm (BCA) (Karaboga, 2009), Differential Evolution (DE) (Karaboga & Cetinkayal, 2006; Liu, Li, & He, 2010), Adaptive Differential Evolution (ADE) (Pan, 2011), Differential cultural algorithm (Gao & Diao, 2010), Particle swarm optimization (PSO) (Najjarzadeh & Ayatollahi, 2008; Krusienski & Jenkins, 2006; Ababneh & Bataineh, 2008), some variants of PSO like Quantum PSO (QPSO) (Fang, Sun, Xu, & Liu, 2006), PSO with Quantum Infusion (PSO-QI) (Luitel & Venayagamoorthy, 2010; Sarangi, Mahapatra, & Panigrahi, 2011), Adaptive inertia weight PSO (Yu, Liu, & Li, 2009), Chaotic mutation PSO (CMPSO)[27-28], Gravitation search algorithm (GSA) (Rshedi, Hossien, & Saryazdi, 2011), Seeker Optimization Algorithm (SOA) (Cai, Chen, & Zhu, 2010), some hybrid algorithms like DE-PSO (Luitel & Venayagamoorthy, 2008) have been applied for the filter design problem. Comparative performance of some of the above algorithms with respect to FIR filter performance characteristics is given in the “Results” section of the paper.

Most of the above algorithms show the problems of fixing algorithms’ control parameters, premature convergence, stagnation and revisiting of the same solution over and over again. In order to overcome these problems, in this paper, a novel optimization algorithm called Firefly algorithm (FFA) (Yang & Deb, 2010; Yang, 2009) and a novel fitness function are employed for the FIR filter design. This paper describes the optimal design of linear phase low pass (LP), high pass (HP), band pass (BP) and band stop (BS) FIR digital filters using FFA approach. Firefly does not prematurely restrict the searching space; the searching space has been varying during the search process. To validate the proposed method the results obtained by FFA are compared with those of a classical optimization technique like Parks–McClellan (PM) algorithm (Parks & McClellan, 1972), and other evolutionary approaches like Real Coded Genetic Algorithm (RGA), conventional PSO, differential evolution (DE) and other already reported results
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