Chapter 16
Improved Design and Optimization of IIR Filters by Cascading of ABC, PSO, and CA

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ABSTRACT

This chapter presents a technique for the design and optimization of the IIR filters by cascading the nature-inspired algorithms including ABC, PSO, and CA. All these algorithms are applied in Low Pass IIR filter and High Pass IIR filter to obtain the optimized filter coefficients so as to minimize the difference between an ideal magnitude response and the desired magnitude response. Finally, IIR filter magnitude response curves and the achieved fitness values for ABC, PSO, and CA are compared to that of the cascaded approach.

INTRODUCTION

Filters are one of the most powerful tools in digital signal processing. The designing filter is one of the essential tasks of digital signal processing. IIR filter optimization involves minimizing the absolute difference between the magnitude response of the ideal filter and the required filter. The magnitude response of the IIR filter $\left|H_i()\right|$ is defined by equation (1) where i denotes the i^{th} candidate solution i.e., set of possible coefficients values. The required filter response is denoted by $\left|H_R(\Omega)\right|$. Ω is taken as normalized frequency $[0\ \pi]$. The i^{th} candidate solution is defined as $x_i = \{b_{i0},\ b_{i1},\ \dots\ b_{iM-1},\ 1,\ a_{i1},\ a_{i2},\ \dots\ a_{iN-1}\}$ where $i = 1,\ 2,\ \dots\ S_N$ (S_N is the total number of input population). Each candidate solution x_i has $N + M$ elements. M elements are numerator coefficients and N elements are denominator coefficients.

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$$\left|H_i()\right| = \left|\frac{\sum_{j=0}^{M-1} b_j e^{-j}}{1-\sum_{k=1}^{N-1} a_k e^{-j}}\right| \tag{1}$$

Each candidate solution is evaluated by calculating the corresponding cost function $CF(x_i)$. To calculate the cost function, the magnitude response of each solution is calculated as defined by equation (1). The cost function is defined by equation (2). The fitness of a particular solution is defined as the reciprocal value of cost function. Thus, the filter coefficients are optimized by minimizing the absolute difference between the magnitude response of the designed and desired filter. A probability value for every solution represents its quality, which is given by equation (3).

$$CF(x_i) = \int_0^{\pi} \left|H_R(\Omega) - H_i(\Omega)\right| d\Omega \tag{2}$$

$$p(x_i) = \frac{CF(x_i)}{\sum_{i=1}^{S_N} CF(x_i)} \tag{3}$$

APPLYING IIR FILTER OPTIMIZATION ALGORITHMS

Before the application of the filter optimization algorithm, each input candidate solution is generated using equation (4) where $x_{\max}$ and $x_{\min}$ denote upper and lower bound for the coefficients, respectively.

$$x_i = x_{\min} + (x_{\max} - x_{\min})\, rand[0,1] \tag{4}$$

This generated input population is given as input to ABC, PSO, CA, and their cascading. The corresponding pseudo-code for the selected algorithms is as given below:

ABC Algorithm

ABC is a population-based optimization algorithm. It is based on the natural behavior of honey bees. There are three types of bees used in the ABC algorithm named employed bee, onlooker bee, and scout bee. Each food source is represented as the set of filter coefficients to be optimized by these three types of bees. Employed bee takes one candidate solution and goes to its neighbors.