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A new design method based on artificial bee colony algorithm for digital IIR filters

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Abstract

Digital filters can be broadly classified into two groups: recursive (infinite impulse response (IIR)) and non-recursive (finite impulse response (FIR)). An IIR filter can provide a much better performance than the FIR filter having the same number of coefficients. However, IIR filters might have a multi-modal error surface. Therefore, a reliable design method proposed for IIR filters must be based on a global search procedure. Artificial bee colony (ABC) algorithm has been recently introduced for global optimization. The ABC algorithm simulating the intelligent foraging behaviour of honey bee swarm is a simple, robust, and very flexible algorithm. In this work, a new method based on ABC algorithm for designing digital IIR filters is described and its performance is compared with that of a conventional optimization algorithm (LSQ-nonlin) and particle swarm optimization (PSO) algorithm.
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Keywords: Digital IIR filters; System identification; Swarm-based optimization; Artificial bee colony algorithm

1. Introduction

Filtering is a process by which the frequency spectrum of a signal is modified, reshaped, or manipulated according to some desired specifications. Design of a digital filter is the process of synthesizing and implementing a filter network so that a set of prescribed excitations results in a set of desired responses [1–4]. Digital filters can be broadly classified into two groups: recursive and non-recursive. The output from a recursive digital filter

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depends on one or more previous output values, as well as on inputs. In other words, it involves feedback. From the digital signal processing point of view, its great advantage is computational economy. A filter characteristic requiring more coefficients in a non-recursive realization can often be obtained using just a few recursive coefficients. However, there are two potential disadvantages [5–7]. First, a recursive filter may become unstable if its feedback coefficients are chosen badly during the adaptation process. This problem can be easily handled by limiting the parameter space. Secondly, recursive designs cannot generally provide the linear-phase responses so readily achieved by non-recursive methods. Apart from these two disadvantages, the possibility of having a multi-modal error surface is another important design challenge for recursive filters. In order to overcome this problem, a design method which can achieve the global minima in a multi-modal error surface is required. However, the conventional design methods, widely employed to tackle the problem, based on gradient search can easily be stuck at local minima of error surface. Therefore, some researchers have attempted to develop the design methods based on modern global optimization algorithms such as the simulated annealing (SA) [8–10], genetic algorithm (GA) [11–16], and differential evolution algorithm [17,18].

Swarm intelligence has become a research interest to many research scientists from various areas in recent years. The swarm intelligence can be defined as any attempt for designing algorithms or distributed problem-solving devices inspired by the collective behaviour of insects and other animal societies [19]. More specifically, swarm intelligence term can be used in a general manner to refer to any restrained collection of interacting agents or individuals. The classical examples of swarm: bees swarming around their hive; a colony of ants; a flock of birds; and an immune system which is a swarm of cells and a crowd that is a swarm of people. Recently, particle swarm optimization algorithm has been introduced for numerical optimization problems [20] and successfully applied to digital filter design and other real-world problems [21,22]. PSO algorithm that is a population-based stochastic optimization technique models the social behaviour of bird flocking or fish schooling [20] and is well adapted to the optimization of nonlinear functions in multi-dimensional space. PSO consists of a swarm of particles moving in a search space of possible solutions for a problem. Every particle has a position vector representing a candidate solution to the problem and a velocity vector. Moreover, each particle contains a small memory that stores its own best position seen so far and a global best position obtained through communication with its neighbour particles. Miranda and Fonseca [23] have proposed an improved version of PSO called evolutionary particle swarm optimization (EPSO). In [23], it is presented that EPSO which joins together the characteristics of evolutionary and of particle swarm algorithms is much more reliable than PSO for practical applications.

In 2005, Karaboga [24] introduced a bee swarm algorithm called artificial bee colony (ABC) algorithm for numerical optimization problems; and Basturk and Karaboga [25,26] compared the performance of ABC with that of some other well-known population-based optimization algorithms. In this work, firstly the performance comparison of PSO, EPSO, and ABC algorithms are presented on a set of numeric test functions. Secondly, a new method based on ABC algorithm is described for designing IIR filters. The paper is organized as follows: Section 2 presents ABC algorithm. Section 3 describes the problem. In Section 4, the performance of ABC is compared with that of PSO and EPSO on a set of a well-known numeric test functions [23] and LSQ-nonlin, which is a conventional

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