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Synergy of evolutionary algorithm and socio-political process for global optimization

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ABSTRACT

This paper proposes a hybrid approach by combining the evolutionary optimization based genetic algorithm (GA) and socio-political process based colonial competitive algorithm (CCA). The performance of hybrid algorithm is illustrated using standard test functions in comparison to basic CCA method. Since the CCA method is newly developed, very little research work has been undertaken to deal with curse of dimensionality and to improve the convergence speed and accuracy of the basic CCA algorithm. The proposed CCA–GA algorithm is then used to tune a PID controller for a real time ball and beam system. Simulation results were reported and the hybrid algorithm indeed has established superiority over the basic algorithms with respect to set of functions considered and it can easily be extended for other global optimization problems.

1. Introduction

The era of evolutionary computation started with genetic algorithms in the past three decades. Amounts of applications have benefited from the utilization of GA (Chaiyaratana & Zalzala, 1997). Potter and De Jong (1994) have demonstrated the use of co-operative co-evaluation GA in multivariable functional optimization. Breeder genetic algorithm (BGA) (Muhlenbein & Schlierkamp-Voosen, 1993) is first introduced by Muhlenbein et al. The major difference lies in the method of selection in comparison to simple GA. A typical task of GA is to find the best set of values in a predefined set of free parameters associated with either a process model or a control vector. The GA uses the basic reproduction operators such as crossover and mutation to produce the genetic composition of a population. Efforts are being made in the enhancement of conventional algorithm (Chen & Yao, 2008; Francisco & Manuel, 2000; Yang & Tinos, 2008; Zhang, Lou, Gao, Liu, & Sun, 2008). GA with neural network and fuzzy control (Siddique & Tokhi, 2002) are used extensively to optimize nonlinear and multivariable systems. In the past, researches were carried out in using hybrid genetic algorithm approaches for optimization problems. Buczak and Uhrig proposed a novel hierarchal fuzzy-genetic (Buczak & Uhrig, 1996) information fusion technique. Constraint handling is one of the major concern for solving the optimization problems using GA. Chootinan and Chen proposed a gradient information (Chootinan & Chen, 2006), derived from the constraint set, to systematically repair infeasible solutions.

Though the GA methods were successful to solve complex optimization problems, recent search has identified some deficiencies in GA performance (Eberhart & Shi, 1998). This degradation in efficiency is apparent in applications with highly *epistatic* objective functions (i.e. where the parameters being optimized are highly correlated), the genetic operators alone cannot ensure better fitness of offspring because chromosomes in the population have similar structure and their average fitness are high toward the end of evolutionary process. Research is still on to increase the efficiency of GA by hybridization (Lee & Lee, 2005). Yang and Tinos (2007) proposes a hybrid immigrants scheme that combines the concept of elitism, dualism and random immigrants to address dynamic optimization problems.

Esmaeil, Farzad, Ramin, and Caro (2008) first proposed the colonial competitive algorithm (CCA) in 2008. Unlike the current evolutionary algorithms, such as genetic algorithm (GA) and simulated annealing (SA) (Mantawy, Abdel-Magid, & Abido, 1999) that are computer simulation of natural processes such as natural evolution and annealing processes in materials, CCA uses imperialism and imperialistic competition, socio-political evolution process, as source of inspiration. The comparison between CCA and GA was illustrated by designing a PID controller for distillation column system (DCS). CCA proved to be superior to GA for a MIMO model.

In this article we have come up with a hybrid optimization technique, which synergistically couples the GA and CCA. The proposed algorithm is validated using test functions and for PID controller tuning. The rest of the paper is organized as follows: Section 2 provides a brief literature overview of the genetic algorithm followed by the proposed hybrid approach based on CCA and GA. The algorithm is then validated using standard test

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functions and implemented on practical ball–beam system in Section 3 followed by conclusions and future work.

2. GA–CCA hybrid system

2.1. Genetic algorithms

In GA, a candidate solution for a specific problem is called an individual or a chromosome and consists of a linear list of genes. Each individual represents a point in the search space, and hence a possible solution to the problem. A population consists of finite number of individuals. Each individual is decided by an evaluating mechanism to obtain its fitness value. Based on this fitness value and undergoing genetic operators, a new population is generated iteratively with each successive population referred to as a generation. Sexual reproduction allows some exchange and re-ordering of chromosomes, producing offspring that contain a combination of information from each parent. This is the recombination operation, which is often referred to as crossover because of the way strands of chromosomes crossover during the exchange. Diversity in the population is achieved by mutation. Genetic algorithms are ubiquitous nowadays, having been successfully applied to numerous problems from different domains, including optimization, automatic programming, machine learning, operations research, bioinformatics, and social systems.

2.2. Colonial competitive algorithm

In CCA, a candidate solution for a specific problem is called a country in which some having the least cost are selected as imperialist states and rest form the colonies of these imperialists. The division of all the colonies of initial countries is based upon the fitness value. The imperialist states together with their colonies form some empires. The colonies in each of the empire start moving towards their imperialist countries, based upon a simple model of assimilation policy. The total power of an empire is defined by the power of imperialist country and percentage of mean power of its colonies. Then the imperialistic competition begins among all the empires. Any empire that is not able to succeed in this competition cannot increase its power shall be eliminated. Based upon this competition, the power gradually increases for some empires and decreases for others. This results in the collapse of weak empires. The movement of colonies toward their relevant imperialist states along with competition among empires and also the collapse mechanism cause all the countries to converge to a state in which their exist just one empire in the world and all the other countries are colonies of that empire. In this new world, colonies have the same position and power as the imperialist.

2.3. The hybrid algorithm

This paper focuses on hybrid system using GA and CCA. The influence of crossover and mutation in GA has been studied and it is found that using CCA and GA, number of iterations increases with higher dimensions and leads to sub optimal solutions. However, a hybrid system of CCA and GA speeds up the running time using less iteration and leads to optimal solution. We used the following operation of GA.

2.3.1. Ranking and selection

In a minimization problem of function $J(\theta)$, a 'ranking' operation (Back, 1996) is performed where individuals are sorted in decreasing $J(\theta)$ value first, and then, $J(\theta)$ is replaced by its position. Each individual has a new cost function value $J'(\theta)$.

Selection is made by the operator known as *Stochastic Universal Sampling* (*SUS*) (Baker, 1987). If N_{ind} is the number of individuals, then the survival probability of an individual $P(\theta_i)$, is guaranteed to be:

$$P(\vec{\theta}_i) = \frac{J'(\vec{\theta}_i)}{\sum_{j=1}^{Nind} J'(\vec{\theta}_j)} \tag{2.3.1}$$

2.3.2. Crossover operation

An extended intermediate recombination (Mühlenbein & Schlierkamp-Voosen, 1993) is used for the hybrid algorithm as:

$$z_i = x_i + \alpha_i(y_i - x_i), \quad i = 1, \ldots, n \tag{2.3.2}$$

Table 1
Benchmark functions used.

Function	Mathematical representation
Sphere	$f_1(x) = \sum_{i=1}^{n} x_i^2$
Rosenbrock	$f_2(x) = \sum_{i=1}^{n-1} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2]$
Rastrigin	$f_3(x) = \sum_{i=1}^{n} [x_i^2 - 10\cos(2\pi x_i) + 10]$
Griewank	$f_4(x) = \frac{1}{4000}\sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n} \cos\left(\frac{x_i}{\sqrt{i}}\right) + 1$

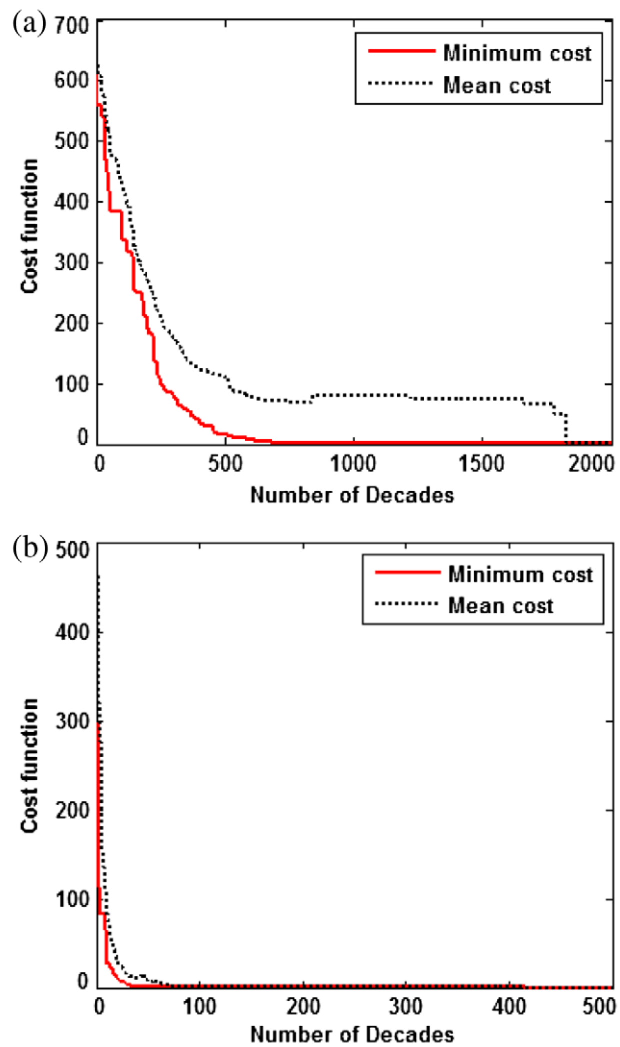

Fig. 1. Fitness profile using CCA and CCA–GA algorithm for sphere function. (a) Fitness profile using CCA. (b) Fitness profile using CCA–GA algorithm.