Applied Soft Computing 11 (2011) 11–22

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

Hybrid GA–BF based intelligent PID controller tuning for AVR system

Dong Hwa Kim *

Dept. of Instrumentation and Control Eng., Hanbat National University, 16-1 San Duckmyong-Dong Yuseong-Gu, Daejeon City 305-719, Republic of Korea

ARTICLE INFO

Article history:
Received 19 September 2005
Received in revised form 5 November 2007
Accepted 9 January 2009
Available online 24 October 2009

Keywords:
Genetic Algorithm
Bacterial Foraging optimization
Hybrid system
Optimal algorithm

ABSTRACT

This paper deals with hybrid system (GA–BF) based on the conventional GA (Genetic Algorithm) and BF (Bacterial Foraging) which is the social foraging behavior of bacteria. A variety of test function is introduced and simulated to illustrate the characteristics and performance by mutation, crossover, variation of step size, variation of chemotactic step, and variation of lifetime of bacteria in the proposed hybrid system GA–BF. The simulated results represent that the proposed method is highly satisfactory. This approach provides us with novel hybrid model based on foraging behavior and also with a possible new connection between evolutionary forces in social foraging and distributed nongradient optimization algorithm design for global optimization over noisy surfaces.

1. Introduction

In the last decade, evolutionary computation based approaches have received increased attention from the engineers dealing with problems which could not be solved using conventional problem solving techniques [1–7]. A typical task of a GA in this context is to find the best values of a predefined set of free parameters associated with either a process model or a control vector. One of the active areas of research in GA is system identification [12–16]. A recent survey of evolutionary algorithms for the evaluation of improved learning algorithm and control system engineering can be found in Ref. [12,16,18]. The general problem of evolutionary algorithm based engineering system design has been tackled in various ways. GA has also been used to optimize nonlinear system strategies. Among them, a large amount of research is focused on the design of fuzzy controllers using evolutionary algorithm approaches. GA could be used for developing the knowledge base about the controlled process in the form of linguistic rules and the fine-tuning of fuzzy membership function [18].

A possible solution to a specific problem can be encoded as an individual (or a chromosome), which consists of group of genes. Each individual represents a point in the search space and a possible solution to the problem can be formulated. A population consists of a finite number of individuals and each individual is decided by an evaluating mechanism to obtain its fitness value. Using this fitness value and genetic operators, a new population is generated iteratively which is referred to as a generation. The GA uses the basic reproduction operators such as crossover and mutation to produce the genetic composition of a population. The crossover operator produces two offsprings (new candidate solutions) by recombining the information from two parents. As mutation operation is a random alteration of some gene values in an individual, the allele of each gene is a candidate for mutation, and its function is determined by the mutation probability. Many efforts for the enhancement of traditional GAs have been proposed [21–23]. Among them, one category focuses on modifying the structure of the population or on the individual's role [15]. Some examples are distributed GA [15], cellular GA [19] and symbiotic GA. Another category is focused on modification/efficient control of the basic operations, such as crossover or mutation, of traditional GAs [19].

On the other hand, as natural selection tends to eliminate animals with poor foraging strategies through methods for locating, handling, and ingesting food and favor the propagation of genes of those animals that have successful foraging strategies, they are more likely to apply reproductive success to have an optimal solution [25,26]. After many generations, poor foraging strategies are either eliminated or shaped into good ones. Logically, such evolutionary principles have led scientists in the field of foraging theory to hypothesize that it is appropriate to model the activity of foraging as an optimization process. Since a foraging animal takes actions to maximize the energy obtained per unit time spent foraging, in the face of constraints presented by its own physiology, such as sensing and cognitive capabilities and environment (e.g., density of prey, risks from predators, physical

---

* Tel.: +82 42 821 1170; fax: +82 821 1164.
E-mail address: kimdh@hanbat.ac.kr.
URL: http://www.aialab.net

1568-4946/$ – see front matter © 2010 Published by Elsevier B.V.
doi:10.1016/j.asoc.2009.01.004

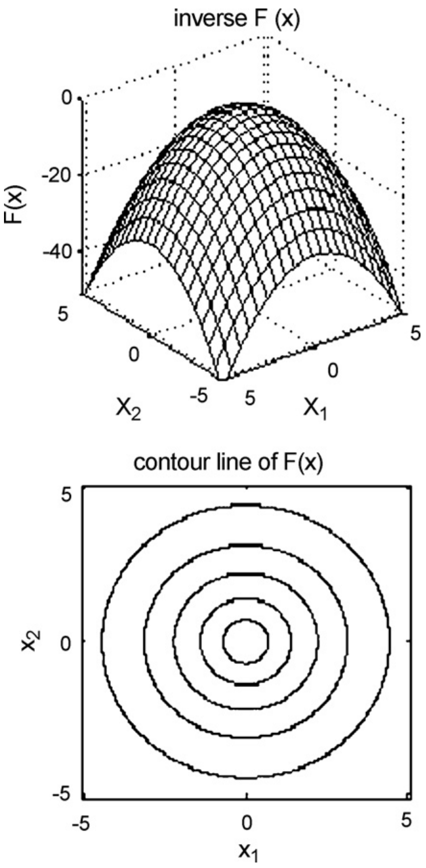

Fig. 1. Contour of test function f_1.

characteristics of the search area), evolution can provide optimization within these constraints and essentially apply to engineering field by what is sometimes referring to as an optimal foraging policy. That is, optimization models can provide for social foraging where groups of parameters communicate to cooperatively forage in engineering.

As the hybrid system, Refs. [32,33] suggest optimal solution, In Ref. [32], they use hybrid least square bacterial strategy, Ref. [33] GA–BF strategy for tuning including experiments.

First, this paper provides a brief literature overview of the area of Bacterial Foraging as it forms the biological foundation for this paper. Then, this paper also focuses on dealing with an enhanced optimal solution using a hybrid approach consisting of BA (Bacterial Foraging) and GA (Genetic Algorithm). Finally, we focus on evidence for the proposed hybrid system by simulating through various test functions.

2. Hybrid system consisting of GA and Bacteria Foraging

As mentioned above, foraging behavior of bacteria [25,26] can be found using, for instance, dynamic programming. Search and optimal foraging decision-making of animals can be used to engineering. To perform social foraging an animal needs communication capabilities, and it can gain advantages in that it can exploit essentially the sensing capabilities of the group, the group can gang-up on large prey, individuals can obtain protection from predators while in a group, and in a certain sense the group can forage with a type of collective intelligence.

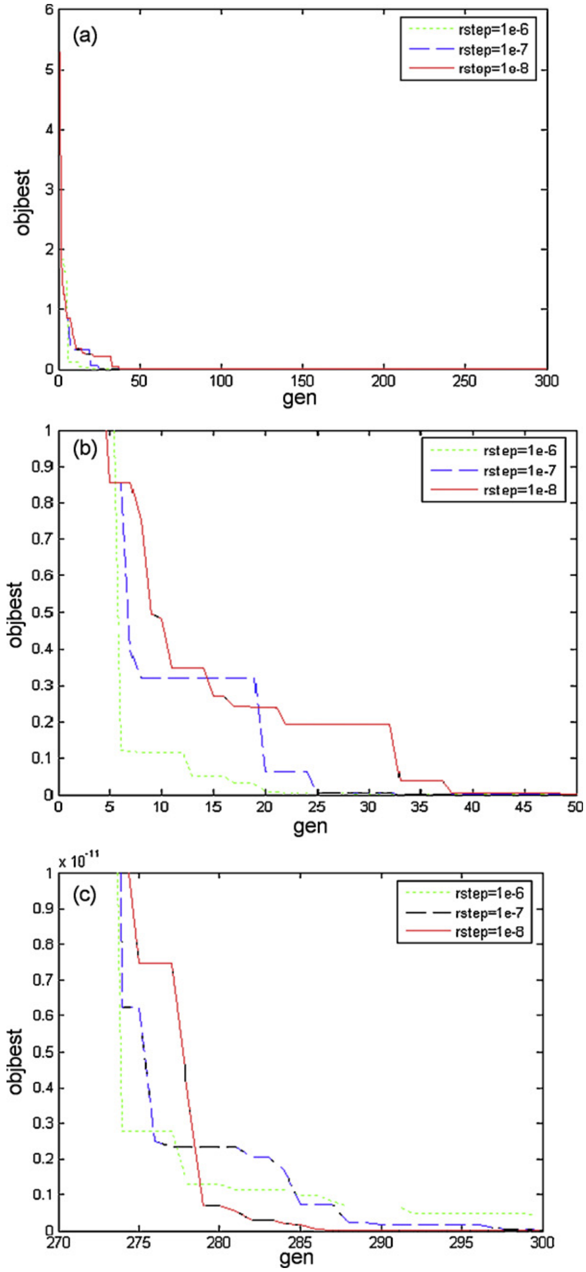

Fig. 2. (a) Characteristic of variables to variation of step size (generations = 1–30). (b) Characteristic of variables to variation of step size (generations = 1–50). (c) Characteristic of variables to variation of step size (generations = 270–300).

2.1. Overview of chemotactic behavior of *Escherichia coli*

This paper considers the foraging behavior of *E. coli*, which is a common type of bacteria as mentioned in the previous comment [25,26]. Its behavior to move comes from a set of up to six rigid

Table 1
Parameter values to step size of bacteria.

Step size	$x1$	$x2$	$x3$	Optimal objective function	Average objective function
1.0E−5	3.87E−13	6.60E−13	2.92E−07	−5.43E−07	−8.98E−08
1.0E−6	2.85E−14	2.34E−13	−5.52E−08	1.50E−07	−5.45E−08
1.0E−7	5.01E−16	1.43E−15	−1.70E−08	−1.44E−08	−2.31E−09