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An Artificial Bee Colony Algorithm Based on Multiobjective and Nondominated Solution Replacement Mechanism for Constrained Optimization Problems

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Abstract. Artificial bee colony (ABC) algorithm is one of the most popular swarm intelligence algorithms. Owing to its simpleness and effectiveness, it has been widely applied in many fields. Many modified versions of ABC algorithm were used to solve constrained optimization problems (COPs). This paper introduces an artificial bee colony algorithm based on multiobjective and nondominated solution replacement mechanism (MONABC) for solving COPs. This new approach presents four modifications on the foundation of the original ABC algorithm. The COPs are converted into unconstrained multiobjective optimization problems (MOPs), and the hybrid search mechanism of small population is applied in the employed bee phase. Moreover, nondominated solution replacement mechanism is devoted to updating the population. According to the dominating ability and feasibility, a new following probability formula based on the overall rank is proposed. In the scout bee phase, new archive and replacement mechanism will be constructed. To verify the performance of our approach, MONABC algorithm is tested on 24 and 18 well-known constrained problems from 2006 and 2010 IEEE Congress on Evolution Computation (CEC 2006 and 2010). The results indicate that MONABC is competitive with the state-of-the-art algorithms for solving COPs and MOPs.

AMS subject classifications: 65C35, 82B31, 90C26

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1. Introduction

Constrained optimization problems (COPs) have been widely applied in practical economy and engineering fields. Among these problems, the general COP is uniformly defined

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as follows:

$$
\begin{aligned}
\min_{x \in R^D} \quad & f(x) \\
s.t. \quad & g_l(x) \leq 0, \quad l = 1, \cdots, q; \\
& h_l(x) = 0, \quad l = q+1, \cdots, m,
\end{aligned} \tag{1.1}
$$

where $x \in R^D$ represents a solution vector with D dimensions, x_{ij} is the j-th dimension of the solution x_i, $f(x)$ is objective function. $g_l(x)$ are inequality constraints, $h_l(x)$ are equality constraints. q is the number of inequality constraints and $m - q$ is the number of equality constraints. Objective functions and constraint functions can be linear or nonlinear. The component of each solution x_i is bounded by lower and upper limits $L_j \leq x_{ij} \leq U_j$, which consists of the search space $\mathscr{S} \subseteq R^D$, and $\mathscr{F}$ is feasible region which is the set of all solutions satisfying the constraints. With a predefined parameter ϵ which is set to 0.0001 in this paper, the constraint violation of x is described as

$$
CV(x) = \sum_{l=1}^{q} \max(0, g_l(x)) + \sum_{l=q+1}^{m} \left| H_l(x) \right|, \tag{1.2}
$$

where

$$
H_l(x) = \begin{cases} |h_l(x)|, & \text{if } |h_l(x)| - \epsilon > 0; \\ 0, & \text{otherwise.} \end{cases} \tag{1.3}
$$

Constrained optimization problems are one of main research directions in optimization field. Applying swarm intelligence algorithms to solve COPs has significantly grown in the past decade, which urges some additional techniques of handling constraints to be proposed. As a consequence, all kinds of constraint handling techniques have been developed [9, 12, 20, 36, 37, 40].

Furthermore, a number of researchers put forward multiobjective techniques to deal with constraints. Constrained optimization problems are converted into unconstrained multiobjective optimization problems (MOPs), and the relevant concepts such as Pareto dominance and Pareto ranking of multiobjective optimization [10] are applied to solve COPs. According to the difference between MOPs and primitive COPs, combining with characteristic of intelligence algorithms, many multiobjective methods were proposed [6–8, 47, 49].

In this paper, we put forward an artificial bee colony algorithm based on multiobjective and nondominated solution replacement mechanism (MONABC) for solving COPs. The MONABC algorithm mainly makes four modifications. Firstly, the original COPs are converted into unconstrained multiobjective optimization problems. The basic artificial bee colony (ABC) algorithm mainly focused on exploiting in the employ bee phase, hence, the new hybrid search mechanism is applied in the employ bee phase to speed up local search. Secondly, the individuals in the population are sorted on the grounds of the dominating ability and feasibility and their overall ranks are obtained accordingly. On the basis of this, an new following probability formula is constructed. Thirdly, nondominated solution