Information Sciences 305 (2015) 320–348

Contents lists available at ScienceDirect

Information Sciences

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

A real-coded genetic algorithm with a direction-based crossover operator

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ARTICLE INFO

Article history:
Received 5 October 2012
Received in revised form 14 November 2014
Accepted 30 January 2015
Available online 11 February 2015

Keywords:
Evolutionary algorithm
Real-coded genetic algorithm
Parallel structure
Real-parameter optimization
Data-driven optimization scheme
Parameter tuning

ABSTRACT

In this paper, we develop a parallel-structured real-coded genetic algorithm (RCGA), named the RGA-RDD, for numerical optimization. Technically, the proposed RGA-RDD integrates three specially designed evolutionary operators – the Ranking Selection (RS), Direction-Based Crossover (DBX), and the Dynamic Random Mutation (DRM) – as a whole to mimic a specific evolutionary process. Unlike the conventional RCGAs that perform evolutionary operators in a series framework, the RGA-RDD embeds a coordinator in the inner parallel loop to organize the operations of the DBX and DRM so that a higher possibility of locating the global optimum is ensured. Besides, based on the results of a systematic parametric analysis, we provide a parameter selection guideline for the settings of the proposed RGA-RDD. Furthermore, a data-driven optimization scheme, which incorporates the uniform design for design of experiments and a shape-tunable neural network for auxiliary decision support, is applied to search for an optimal set of the algorithm parameters. The effectiveness and applicability of the proposed RGA-RDD are demonstrated through a variety of benchmarked optimization problems, followed by comprehensive comparisons with some existing state-of-the-art evolutionary algorithms. Extensive simulation results reveal that the performance of the proposed RGA-RDD is superior to comparative methods in locating the global optimum for real-parameter optimization problems, especially for unsolved multimodal and high-dimensional hybrid functions.
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1. Introduction

1.1. A review of conventional real-coded genetic algorithms

In the past few decades, many different types of evolutionary algorithms (EAs) have been proposed to solve optimization problems resulted from diversified fields of science, economics, engineering, and so on. According to the evolutionary mechanisms used, EAs are conventionally classified into the following categories: genetic algorithms (GAs) [7,34,36], evolutionary strategies (ESs) [33,39,60], genetic programming (GP) [69,91], evolutionary programming (EP) [15,57], differential evolution (DE) [19], and those inspired from biology and nature [25,26,44]. Among the developed EA schemes, the genetic algorithms (GAs) are widely recognized as one of the most popular and commonly used optimization methods, and based on

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http://dx.doi.org/10.1016/j.ins.2015.01.026
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which many successful applications have been reported in the literature [13,14,27,49,87,91]. Basically, the GA is a kind of population-based stochastic searching approach that mimics the natural selection and survival of the fittest in the biological world. We note that, among many available coding schemata such as Gray coding [71], integer genes [56], etc., the real-coded genetic algorithms (RCGAs) [34,35] present to be the most intuitive type of GAs for solving real-parameter optimization problems because of the ability of representing the numerical solution directly with a real number [50,63] and without requiring the coding and decoding procedures. Furthermore, in addition to the theoretical studies [41,46,72] that have been conducted to prove the solution efficiency and stability of RCGAs, several remarkable works [30,40,43,55,65,85,93] have revealed that the RCGAs outperform several counterpart GAs in many real-world optimization applications, especially for high-dimensional or high-accuracy problems.

From a technical point of view, the RCGAs essentially make use of three fundamental evolutionary operators – selection, crossover, and mutation – to search for an optimal solution. Each operator is featured with a specific mechanism to approach better solutions. The selection operator chooses those potential chromosomes among the whole population, and those selected will receive the subsequent crossover manipulation. The crossover operator generates some new candidate chromosomes (offspring) by recombining the genetic information gained from the selected parent chromosomes. The mutation operator randomly changes the gene of chromosomes in order to prevent premature convergence; as a consequence, it provides an opportunity to avoid being trapped by a local optimum. The conventional RCGAs commonly operate these three kinds of operators in a series framework as shown in Fig. 1. Despite many successful applications of using the conventional RCGAs were reported, we found from a literature survey that there has been an increasing interest in improving the RCGA's solution efficiency. As a brief summary, we classify the recent attempts made to cultivate the RCGAs into the following categories: the determination of the optimal population size [1,28,37,48], the discovery of effective methods to initialize

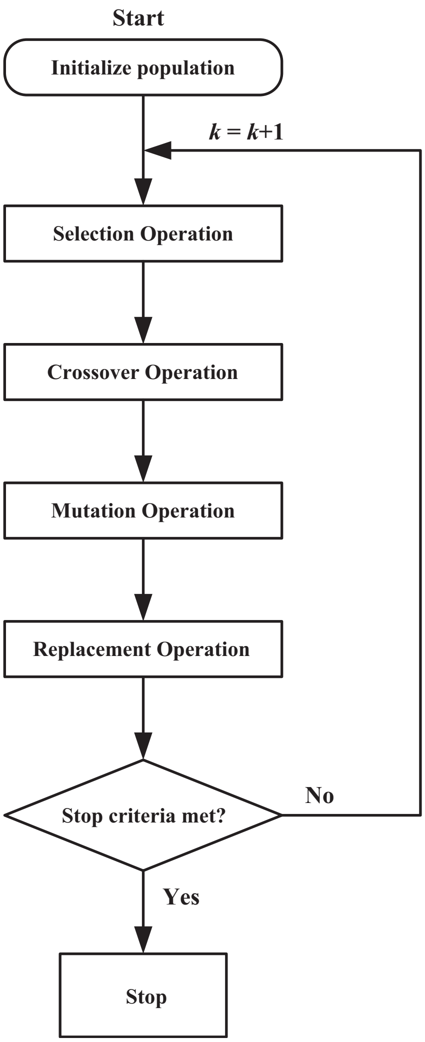

Fig. 1. The flow chart of the conventional RCGA optimization scheme.

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