Linear adjustment of a search space in genetic algorithm

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Abstract

The concept of a search space adjustment is developed in order to improve a performance of genetic algorithms (GAs) for solving numerical constrained optimization problems. Implementation of a linear adjustment of a search space size significantly reduces a computational cost to obtain an optimal solution in comparison with other methods of GA. Ability of this approach is demonstrated by using several test cases. Other constrained optimization algorithms are also used to make comparisons with represented approach.

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1. Introduction

During the last decade genetic algorithms (GAs) quite successfully applied in a wide variety of applications (Gen and Cheng, 1997; Goldberg, 1989). However, normally they applied for global optimization problems without constraints, and, consequently, it is necessary to find ways of incorporating the constraints into the fitness function.

In general to find an optimizer $x^*$ is a main task for solving the global numerical optimization of nonlinear programming problem

$$f(x^*) = \min f(x)$$

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where \( \bar{x} = [x_1, ..., x_n] \in \mathbb{R}^n \).

The objective function \( f \) is well-described in the search space \( S \subseteq \mathbb{R}^n \), which is the constrained section on the n-dimensional Euclidean space. The domain of variables is determined by their lower and upper bounds:

\[
x_l(j) \leq x_j \leq x_u(j), \quad 1 \leq j \leq n
\]

The search area in a global numerical optimization problem (GOP) is more constrained to a viable region \( F \), where \( F \subseteq S \) by a set of limitations:

\[
g_i(\bar{x}) \leq 0, \quad 1 \leq i \leq p \quad \text{and} \quad h_r(\bar{x}) = 0, \quad 1 \leq r \leq q.
\]

Usually the equality limitations \( h_r(\bar{x}) \) are substituted by a set of inequalities \( h_r(\bar{x}) \leq \delta \) and \( h_r(\bar{x}) \geq -\delta \) with a small \( \delta > 0 \).

Various constraint-handling methods by using GA during the last decade were proposed for solving GOP. Several surveys of constraint-handling techniques are available (Coello Coello, 2002; Michalewicz, 1996; Michalewicz and Schoenauer, 1996), which discuss in some details advantages and disadvantages of these techniques. Handling the constraints in GOP can be done by reduction the search area to the viable region in which the global optimal solution is situated. Koziel and Michalewicz (1999) recycled a conventional genetic algorithm to discover the crossing points of a line with the margin of the viable section to cover the search area nearer to a viable section. However, disadvantages of this approach are the requirements of extra calculations to assess some problem-dependent factors experimentally, and to discover all crossing points of a line with the margin of the viable section by means of a binary search that is the main part of the method. The method is also based on a high resolution of a binary coding of individuals to confine precisely the viable search area, which is very essential if the global optimum is situated on the margins. Kim and Husbands (1998) recommended a similar tactic that recycled Riemann mappings to convert the possible region into a shape that simplified the search of GA. Their tactic could be applied only for tasks of low dimensionality (only four or less variables can be used).

There are some approaches that dynamically adjust a size of a search area to the hopeful region where the global optimum may is situated. Arakawa and Hagiwara (1998) suggested a GA that adaptively alters the range of variables and repeatedly increasing the precision of the solution. The method adopts that the offspring are dispersed according to the normal distributions in the array of the variables. Based on this hypothesis the range of the variables changes accordingly around the mean of existence individuals. Djurisic, Elazar and Rakic (1997) compacted a search space size of the variables to increase precision of the discrete samples in the solution space. The search space size is compacted by affecting the upper and lower limits of the field of variables to the mean of each variable in the population. Chelouah and Siarry (2000) suggested a method to reduce slowly the original search area of variables and to concentrated it on the best solution found. The attenuation technique as constrained-handling method for evolutionary algorithms was suggested before by Hernández Aguirre et al. (2004). The method chains the use of multiobjective optimization principles with an instrument that emphasizes the examined effort onto specific areas of the possible region by reduction of the controlled exploration space. Amirjanov (2004) suggested the changing range GA (CRGA) that recycled a similar tactic to diminish recursively with the fixed coefficient \( k<1 \) the before determined search space of the variables. He examined the routine of GA for two cases: first, the search area is focused on the best result found, and second, the search area is focused on the mean value of each variable. In the current study the performance of a CRGA with the linear law for reducing the original search space size of the variables is explored. This approach divides a number of generations for two parts: the first part of generations is devoted for moving the population to a feasible region by reducing a search space size, but the second part of generations is dedicated for moving the search space with a fixed size towards the global optimum.

In the current study twelve test cases (Koziel and Michalewicz, 1999) with constraints were nominated to assess the suggested method. Other algorithms devoted for solving numerical optimization problems are also used to make comparisons with represented approach.
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