

Enhanced Directed Differential Evolution Algorithm for Solving Constrained Engineering Optimization Problems

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ABSTRACT

The performance of Differential Evolution is significantly affected by the mutation scheme, which attracts many researchers to develop and enhance the mutation scheme in DE. In this article, the authors introduce an enhanced DE algorithm (EDDE) that utilizes the information given by good individuals and bad individuals in the population. The new mutation scheme maintains effectively the exploration/exploitation balance. Numerical experiments are conducted on 24 test problems presented in CEC'2006, and five constrained engineering problems from the literature for verifying and analyzing the performance of EDDE. The presented algorithm showed competitiveness in some cases and superiority in other cases in terms of robustness, efficiency and quality the of the results.

KEYWORDS

Constrained Optimization, Differential Evolution, Engineering Optimization, Handling Constraints, Novel Mutation

1. INTRODUCTION

In Constraint Optimization Problems (COPs), the process of finding the optimal value for an objective function without violating a given number of constraints is considered as a challenging and complex task due to the nature of those problems (de Melo & Carosio, 2012; Mohamed 2017; Mohamed & Sabry, 2012; Dong & Wang, 2014; Elsayed et al., 2014). Over the past decade, Researchers have proposed several types of computational algorithms and many constraints handling techniques in order to solve COPs. (Coello, 2002) presented a complete study in detail. (Wang et al. 2007) proposed (HCOEA) which based on combining global and local search models to solve multi-objective optimization problems. (SAMO-GA) was proposed by (Elsayed et al., 2011) and has shown a good improvement compared to other GA variants. Evolutionary strategies and evolutionary programming have been used to solve COPs. (Mezura-Montes & Coello, 2005) proposed SMES that keeps infeasible solutions in the population, it was very competitive mechanism. (Mallipeddi & Suganthan, 2010) proposed ECHT-EP2 that was competitive for the state-of-art algorithms. Recently, Swarm Intelligence (SI) that is nature inspired algorithms has attracted many researchers. (Yang, 2009) proposed the Firefly Algorithm. (Karaboga, 2005) proposed the artificial bee colony, and (Dai et al., 2006) recently proposed Seeker Optimization Algorithm. (Elsayed et al., 2014) proposed SAM-PSO that performed

DOI: 10.4018/IJAMC.2019010101

better than other PSO variants. (Mezura-Montes & Cetina-Domínguez, 2012) proposed M-ABC with four modifications to improve its performance. (Tuba & Bacanin, 2014) proposed SOA-FS that outperforms other state-of-art SI algorithms.

Differential evolution presented by (Storn & Price, 1995) is a heuristic population based algorithm and considered as the most simple, powerful and reliable algorithms to solve global optimization problems over continuous space. DE proved to be very successful in solving COPs when combined with the constraint handling techniques. (Becerra & Coello, 2006) proposed a cultural algorithm that uses different knowledge sources to affect the DE variation operator. A multi-member DE introduced by (Zhang et al., 2008), in which the promising infeasible solution is kept during the process of evolution. (Mohamed & Sabry, 2012) proposed a novel directed mutation for handling equality constraints (COMDE). (Elsayed et al., 2012) proposed (SAMSDE) to solve COPs, in which the population is divided into sub-populations, each sub-population is evolved using its own mutation and crossover. (Sarker et al., 2014) proposed (DE-DPS), in which three sets of DE parameters are considered, and a random combination of F and CR is assigned to each individual.

Motivated by this discussion, an enhanced directed mutation rule is proposed in order to balance the exploration / exploitation and to improve the convergence speed. The proposed algorithm is tested for CEC'2006 test functions and five widely used engineering problems to show superiority and competitiveness performance compared to recent algorithms.

COPs formulation is presented in the next section. DE algorithm is presented in Section 3. The proposed EDDE is presented in detail in section 4. Section 5 presents the setup of the experimentation and the obtained results. Finally, Section 6, summarizes the conclusion

2. COPS FORMULATION AND HANDLING THE CONSTRAINTS

Generally, COP has the following form (Yong, 2009):

$$\text{Min } f(X), X = (x_1, x_2, \dots, x_n) \in \mathbb{R}^n \quad (1)$$

St.:

$$h_i(X) \leq 0, i = 1, \dots, m \quad (2)$$

$$g_i(X) = 0, i = m + 1, \dots, q \quad (3)$$

“Where $X \in \Omega \subseteq S$, Ω is the feasible region, and S is an n -dimensional rectangular space in \mathbb{R}^n defined by the parametric constraints $L_j \leq x_j \leq U_j$, $1 \leq j \leq n$ where L_j and U_j are lower and upper bounds for a decision variable x_j , respectively. Most constraint-handling techniques that's is used in EAs are dealing with inequality constraints only. Therefore, inequality constraints of the form $|g_i(X)| - \varepsilon \leq 0$ are obtained from equality constraints, where ε is the tolerance level.” (Mohamed A. W., 2017)

To handle the constraints, (Deb 2000) proposed a new rule that is based on comparing pair-wise solutions based on the following criteria:

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