Metamodel Assisted Mixed-Integer Evolution Strategies Based on Kendall Rank Correlation Coefficient

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Abstract. Although mixed-integer evolution strategies (MIES) have been successfully applied to optimization of mixed-integer problems, they may encounter challenges when fitness evaluations are time consuming. In this paper, we propose to use a radial-basis-function network (RBFN) trained based on the rank correlation coefficient distance metric to assist MIES. For the distance metric of the RBFN, we modified a heterogeneous metric (HEOM) by multiplying the weight for each dimension. Whilst the standard RBFN aims to approximate the fitness accurately, the proposed RBFN tries to rank the individuals (according to their fitness) correctly. Kendall rank correlation Coefficient (RCC) is adopted to measure the degree of rank correlation between the fitness and each variable. The higher the rank similarity with fitness, the greater the weight one variable will be given. Experimental results show the efficacy of the MIES assisted by the RBFN trained by maximizing the RCC performs.

1 Introduction

Evolution Strategies (ES) [1] are a branch of Evolutionary Algorithms (EA) [2]. Successful as they are, ESs have encountered challenges, one of which is the heterogeneity of the decision variables. There are some real-world optimization problems, whose decision variables are of different types. It usually contains continuous variables, integer variables and nominal discrete variables simultaneously. Canonical Evolution Strategies usually work on optimization problems of homogeneous (typically continuous) decision variables only.

Mixed-integer evolution strategies (MIES) [3] were proposed by Emmerich et al to optimize the rigorous process simulators which is a mixed-integer optimization problem in chemical plant design. MIES can deal with different variable

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types simultaneously, which usually include continuous, integer and nominal discrete. In [3–5], MIES have been employed to successfully solve mixed-integer optimization problems occurring in optical filter design, rigorous process simulators for chemical plant design and image analysis agent for intravascular ultrasound image analysis.

Another challenge to Evolution Strategies is the difficulty in fitness evaluations [6]. As discussed in [6], in many real-world problems, fitness evaluations need a high complexity of performance analyses, which means each single fitness evaluation is highly time-consuming. In some other cases, explicit fitness functions do not exist, therefore human experts are needed for assigning a fitness value to a candidate solution. Both huge time consumption for fitness evaluations and fatigue of human experts will prevent Evolution Strategies from being applied to a wider range of problems. Using a metamodel (also known as surrogates) to estimate the fitness values is a common approach to addressing this kind of problems [6]. Typical metamodels include polynomial models, kriging models, neural networks and support vector machines [7].

The difficulty in fitness evaluations in real-world applications is also a challenge that MIES faces. A straightforward idea for addressing this problem is to use a metamodel-assisted MIES. However, most research on metamodel assisted Evolution Strategies focus on continuous optimization problems [7]. To the best of our knowledge, only one paper has been reported on developing metamodels for MIES [8]. In [8], Li et al chose radial-basis-function networks (RBFNs) [9] as the metamodel, and modified the canonical RBFN to make it more suited for mixed-integer search spaces by introducing a heterogeneous distance metric.

In this paper, we propose a new RBFN to assist MIES. The distance metric of the proposed RBFN is based on the Kendall rank correlation coefficient (RCC) [10]. Before obtaining the distance between two individuals, we first determine the weights for each variable according to the Kendall RCC between variables and the true fitness values. Since the distance metric is related to the rank, we hope that the new RBFN will help MIES to select better individuals, thereby improving the performance of the RBFN assisted MIES.

This paper is organized as follows. In Section 2.1, we introduce MIES together with a formal statement of Mixed-integer optimization problems. Recombination and mutation operators for MIES proposed by Li in [3] are discussed. RBFN assisted MIES are described in Section 2.2, where the modified the distance metric for RBFN proposed in [8] is also presented. In Section 3, we introduce the Kendall rank correlation coefficient [10] and propose a RCC based RBFN for assisting MIES. The performance of the new algorithm is verified on four test problems in Section 4. Section 5 concludes this paper.

2 RBFN Assisted MIES

2.1 Mixed-Integer Evolution Strategies

MIES can deal with different types of variables simultaneously, which usually include continuous, integer and nominal discrete. A mixed-integer global opti-