A Real-Coded Genetic Algorithm using Distance Dependent Alternation Model for Complex Function Optimization

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Abstract

The multi-parental Unimodal Normal Distribution Crossover (UNDX-*m*) that was proposed by Ono et al. and extended by Kita et al for real-coded Genetic Algorithms (GA). shows an excellent performance in optimization problems of highly epistatic fitness functions in continuous search spaces. The UNDX-*m* is a crossover operator that preserves the statistics such as the mean vector and the covariance matrix of the population well. While the crossover operator preserves the statistics of the population, an alternation model used with the crossover is needed to evolve the population through the alternations of the individuals in the population to progress a search. We proposed a distance dependent alternation (DDA) model, which is based on alternations of the elite child with the nearest parent in the family, to progress a search maintaining a diversity of a population. In this paper we show a real-coded GA using the UNDX-*m* combined with DDA model robustly solves 30-dimensional Fletcher-Powell function which is highly multi-modal and has similarity to real-world problems, and has never been solved by every other Evolutionary Algorithms.

1 INTRODUCTION

In solving optimization problems in continuous search spaces by Evolutionary Computation, it is important how to adapt to the fitness landscape of the problem to be solved during search stage for improving performance [Schwefel 95a] [Bäck 96]. Evolution strategies, which utilize adaptive mutation ranges, use recombination operators for global adaptation. Extensions of evolution strategies to multi-parent recombination are also proposed, however these extensions don't show clear improvement in performance [Schwefel 95b] [Eiben 97].

In applying genetic algorithms to optimization problems, we have to appropriately design coding/crossover and generation alternation scheme. It is important to preserve characteristics of good solutions with appropriate coding/crossovers, and to maintain diversity of populations through generation alternation [Goldberg 89]. Real-coded GAs, which use real number vector representation, show higher performance than those based on binary or Gray code representations when GAs are applied to problems in continuous search spaces [Herrera 98] [Salomon 96]. There are many recombination operators proposed for continuous genes, for example Fuzzy recombination [Voigt 95]. The Unimodal Normal Distribution Crossover (UNDX), proposed by Ono et al., shows good performance as crossover operator for the real-coded GAs, by putting proper inheritance into practice on generating offspring [Ono 97] [Kita98]. Kita et al. has extended the UNDX to multi-parental one (UNDX-m) to improve search performance on optimization problems with poorly scaled coordinate systems [Kita 99].

As for the generation alternation models, Satoh et al. proposed a generation alternation model called the minimal generation gap (MGG) model which is more effective than conventional ones in avoiding premature convergence and evolutionary stagnation [Satoh 96] [Satoh 97].

One dimensional UNDX with the MGG alternation model has shown good performance on several benchmark problems. The UNDX treats mainly two parents at one set of crossover operations, and MGG model alternates two individuals. The elite individual in the family survives for pushing search further, and the one more individual selected by roulette wheel technique survives for maintaining diversity of the population. From a viewpoint, the MGG model is matched with the UNDX-1, because both of them treat two individuals.

If we grasp more than three parents at multi-parental extension of the UNDX as only samples for forming distribution of the offspring, we should be able to treat the two parents randomly sampled from the group of parents as candidates of alternation in the MGG model. However, the aforesaid extension of the UNDX to improve search performance sometimes causes the early convergence with the MGG model. The extension on the UNDX changes the distribution of offspring that are created through the crossover operation. That change ought to be an essential adaptation to the fitness landscape where the population resides. While the distribution of the offspring by the extended UNDX is more suitable to yield superior offspring, it has less diversity and tends to converge at the center of parents group. Hence the MGG is not enough to maintain the diversity of population, and another view-point is required to sufficiently maintain the diversity with the extended UNDX.

We proposed a distance dependent alternation (DDA) model that utilizes distance information between individuals in the population as extension of the MGG model [Takahashi 99a]. The MGG model only uses fitness value for alternation, but the DDA model also uses distance information among the parents and the offspring that is relevant to generation alternation. The basic concept of the DDA model is that the elite among the offspring, will alter the nearest parent individual in multi- parental genetic algorithm.

We have applied this scheme combined UNDX-*m*, to a protein folding problem that has very complicated landscape [Takahashi 99b].

In this paper, we apply the real-coded GA using UNDX-*m* with DDA model to complicated benchmark functions, which are high dimensional Rosenbrock function and Fletcher and Powell function, to confirm the superior performance.

In the next and third section, we review the UNDX as crossover operation, the MGG model as a generation alternation model, and the DDA model as advanced alternation scheme. We show the effectiveness of the DDA model with numerical experiments in the fourth section, and discuss the proposed methods in the fifth section.

2 A REAL-CODED CROSSOVER

Ono et al. proposed the unimodal normal distribution crossover (UNDX), which shows an excellent performance in optimization problems of highly epistatic fitness functions in continuous search spaces [Ono 97]. Further, Kita et al. extended it multi-parental one (UNDX-*m*) [Kita 99]. Here we use the UNDX-*m* as a real-coded crossover operation to solve function optimization problems.

2.1 UNDX

The UNDX proposed by Ono et al. generates children obeying a normal distribution around the parents as shown in Fig.1. The normal distribution is centered at the midpoint of parents 1 and 2, and having a standard deviation proportional to the distance between one of the parents and the midpoint in the direction of the line connecting the parents.

Further, the standard deviations in the perpendicular directions are taken proportional to the distance of the third parent and the lines connecting the parent 1 and 2..

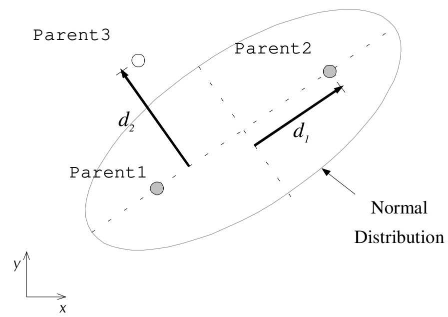

Figure 1 Unimodal Normal Distribution Crossover (UNDX)

2.2 UNDX-*m*

We use the multi-parental version of the UNDX called UNDX-*m* which was extended by Kita et al. This extension is aimed to improve search performance on optimization problems that have poorly scaled coordinate system or have highly compliated fitness landscape. In the UNDX-*m*, *m*+2 parents are selected from the population and the first *m*+1 parents are used to span the *m*-dimensional supspace where the children are mainly distributed obeying a normal distribution. The last parent is used to give perturbation to the children in remaining subspace. UNDX-1 is equivalent to the original UNDX. Please refer to Appendix A added the end of this paper for a detailed definition .

The UNDX-*m* is a crossover operator that preserves the statistics such as the mean vector and the covariance matrix of the population well. Therefore, an alternation model should fill the role to progress a search through the alternations of the individuals in the population

3 ALTERNATION MODELS

Minimal Generation Gap (MGG) Model [Satoh 96] proposed by Satoh et al. as previous alternation model only uses objective values for alternation. We propose utilizing distance information to enhance performance of the alternation model particularly within real-coded GAs.

3.1 PREVIOUS MODEL : MGG

The Minimal Generation Gap (MGG) Model proposed by Satoh et al. is an effective one of generation alternation models [Satoh 96][Satoh 97].

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/FDepVector
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0.8657
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