MULTIPLE PARENTS, MULTIPLE CROSSOVERS AND INCEST PREVENTION IN EVOLUTIONARY COMPUTATION

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Abstract

Multimodal optimization is an always present topic in Computer Systems and Networks design and implementation.
Evolutionary Computation is an emergent field which provides new heuristics to function optimization where traditional approaches make the problem computationally intractable.
The present contribution gives an insight of the current enhancements that can be done in evolutionary techniques, attempting to balance exploitation and exploration to avoid premature convergence during the search process.
Multiple parents, multiple crossovers and incest prevention are three different techniques that when combined showed a substantial benefit: The set of suboptimal solutions are concentrated nearby the optimal solution.
This paper shows the design, implementation and partial performance results when a combination of multiple crossovers on multiple parents and incest prevention is applied to an evolutionary algorithm optimizing two difficult multimodal functions.

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1. Introduction

Balance between exploitation and exploration is a main factor influencing search in an evolutionary algorithm. Extreme exploitation can lead to premature convergence and intense exploration can make the search ineffective [11].

Attempting higher exploitation of previously found solutions, *multiple crossovers per couple* (MCPC) was recently introduced as a new crossover method [7]. Allowing multiple crossovers per couple on a selected pair of parents provided an extra benefit in processing time and similar quality of solutions when contrasted against the conventional approach, which applies a single crossover operation per couple. These results, were confirmed when optimising classic testing functions and harder (non-linear, non-separable) functions.

In the Eiben's *multiparent approach*, offspring creation is based on a larger sample from the search space and consequently larger diversity is supplied. This can help to avoid premature convergence.

Under a different view *incest prevention*, due to Eshelman and Shaffer [6], also showed its benefits to avoid premature convergence in evolutionary algorithms. The method avoided mating of pairs showing similarities based on the parent's hamming distance.

In a previous work we showed an extended approach of incest prevention by maintaining information about ancestors within the chromosome and modifying the selection for reproduction in order to impede mating of individuals belonging to the same "family", for a predefined number of generations.

This novel approach was tested on a set of multimodal functions. Description of experiments and analyses of improved results can be seen in [1].

Despite the above mentioned benefits, due to a reinforcement of selective pressure, MCPC showed in some cases an undesirable premature convergence effect and some adjustment were needed.

Focussing on the exploitation versus exploration equilibrium problem, a previous proposal combined MCPC with an alternative selection method; Fitness Proportional Couple Selection (FPCS) which first, creates an intermediate population of couples where both individuals were chosen by proportional selection. Then a criterion is applied to establish the fitness of a couple and subsequently, couples are selected for crossing-over based on couple fitness [8].

Recently, extending the Eiben's multiparent proposal [2], [3], [4], [5] in a Pareto optimality study, it was found that good results can be obtained by applying *multiple crossovers per mating action* (MCPMA), a natural extension of MCPC, on multiple parents [9].

Encouraged by these results an investigation was conducted to establish the raw effect in performance on a pair of selected optimization problems by using a new *multiple crossovers on multiple parents* (MCMP) method, which allows multiple recombination of multiple parents under *uniform scanning crossover*. Results under MCMP were better in quality and speed of convergence than previous approaches attempting improvements of MCPC and were published elsewhere [10]

In the case of multimodal functions the problem space, also called the *fitness landscape*, provide multiple suboptimal points. Depending on the type of operators used and their frequency of application, the convergence to these suboptimal points can arise. This effect, known as *premature convergence*, is mainly derived from a loss of population diversity before optimal, or at least satisfactory values, have been found.

A possible strategy to maintain population (genetic) diversity, attempting to avoid premature convergence is a mating strategy known as *incest prevention*.

This approach was first used by Eshelman and Schaffer who avoided mating of those pairs showing similarities. As a bit string representation was used for their experiments similarities were determined on the parent's hamming distance.
In our work we used an extended, representation-independent-approach for incest prevention. This goal is achieved by maintaining information about ancestors within the chromosome structure and modifying the selection for reproduction. In this way mating of individuals belonging to the same "family" is avoided for a predefined number of generations.
The present work indicates that allowing multiple crossovers between multiple parents preventing incest, improve the search process in an evolutionary algorithm. Next sections briefly describe the method experiments and analyses of improved results on two hard multimodal functions (Griewank's and Branin's Rcos) and two possible applications.

2. Experiments description

For this report, we choose contrasting results on two multimodal functions of varying difficulty:

f1: Griewangk's Function

$$f_1(x_i) = 1 + \sum_{i=1}^{5} \frac{x_i^2}{4000} - \prod_{i=1}^{5}\left(\cos\left(\frac{x_i}{\sqrt{i}}\right)\right),$$

$x_i = -600:600$, $i = 1:5$;
minimum global value: 0.0

f2: Branins's Rcos Function

$$f_4(x_1,x_2) = \left(X_2 - \frac{5.1}{(4\cdot\pi^2)}\cdot x_1^2 + \frac{5}{\pi}\cdot X_1 - 6\right)^2 + 10\cdot\left(1-\frac{1}{(8\cdot\pi)}\right)\cdot\cos(x_1)+10,$$

$x_1 = -5:10$, $X_2 = 0:15$;
minimum global value: 0.397887

When optimizing the above indicated functions the following experiments were performed:

- Multiple Parents (MP)
- Multiple Parents with Incest Prevention (MPIP)
- Multiple Crossover on Multiple Parents (MCMP)
- Multiple Crossover on Multiple Parents with Incest Prevention (MCMPIP).

Incest prevention was implemented by carrying the ancestors history to prevent incest of individuals with common ancestors in the last two consecutive generations.
To obtain experimental results series of many runs, each with randomised initial population, were performed for each experiment on each function, using proportional selection, binary coded representation, elitism, uniform scanning crossover and bit flip mutation.
For those experiments without incest prevention the population size was fixed to 70 individuals. When incest prevention was implemented , in order to find subsets of n_l

parents for mating with no common ancestors. the size of the population was augmented to 170 individuals.

The number of generations was fixed to 500 and probabilities for crossover and mutation were fixed to 0.5 and 0.005 for *f1* and *f2* .

As an indication of the performance of the algorithms the following relevant performance variables were chosen:

Ebest = (Abs(*opt_val* - best value)/*opt_val*)100

It is the percentile error of the best found individual when compared with the known, or estimated, optimum value *opt_val*. It gives us a measure of how far are we from that *opt_val*.

Epop = (Abs(*opt_val*- pop mean fitness)/*opt_val*)100

It is the percentile error of the population mean fitness when compared with *opt_val*. It tell us how far the mean fitness is from that *opt_val*.

Gbest: Identifies the generation where the best value (retained by elitism) was found.

About results, we briefly say here that important improvements were obtained by combining multiple recombination and incest prevention. Also and more notably is the effect of grouping the final population around the best individual found (optimal or near-optimal). This effect was detected on both testing functions.

3. Conclusions

In contrast with the single crossover per couple approach, Multiple crossover per couple (MCPC) permits more than one crossover operation for each mating pair exploiting features of previously found good solutions. The method showed its benefits and limitations, detailed in previous works.

To overcome these limitation a variant MCMPIP, including recombination of multiple parents and incest prevention is presented here.

The results obtained indicates that this approach mitigates the possible loss of diversity generated by the application of multiple crossovers on a pair of parents and no extra adjustments, used before, seem to be necessary. Consequently the quality of results is at least as good as previous more complex approaches. Additionally, when observing the final population it was detected that all individuals are much more centred surrounding the optimum. This is an important issue when the application requires provision of multiple alternative near-optimal solutions confronting system dynamics as in Computer Networks and Parallel Systems. Also speed of convergence, measured in number of generations, is augmented without increasing the risk of premature convergence.

Although we cannot be conclusive, it seems that by means of this approach the searching space is efficiently exploited by the multiple application of crossovers, efficiently explored by the greater number of samples provided by the multiple parents and premature convergence is avoided by incest prevention.

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