Self-Adaptive Partially Mapped Crossover

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ABSTRACT

Self-adaptive crossover is a step towards exploiting the structure of problems automatically by evolution. We present a self-adaptive extension of the partially mapped crossover (PMX) operator that controls the crossover points. Because the link between strategy parameters and fitness is weak for self-adaptive crossover, superior results were hard to gather in the past. We can now report encouraging experimental results for the PMX on the traveling salesman problem (TSP) as an example for combinatorial problems.

Categories and Subject Descriptors

I.2.8 [**Computing Methodologies**]: Artificial Intelligence—*Problem Solving, Control Methods, and Search*

General Terms

Algorithms, Experimentation

1. PRELIMINARY WORK

Up to now, the application of self-adaptive crossover is mainly restricted to the control of the crossover probability p_c. The first attempt to integrate self-adaptation into crossover was punctuated crossover by Schaffer and Morishima (1987). Meyer-Nieberg and Beyer [2] point out that the standard one- or k-point crossover operators for bit string representations exhibit features of a self-adaptive mutation operator.

2. SELF-ADAPTIVE PMX

Partially mapped crossover (PMX) was designed for TSP by Goldberg and Lingle [1] and enhanced by Whitley in 1995. The self-adaptive partially mapped crossover (SA-PMX) keeps the crossover points Λ_1 and Λ_2 in the strategy part Σ and evolves them during the optimization process. Considering ρ parents, it has to be specified which of the ρ crossover point sets Σ_i with $0 \leq i \leq \rho$ have to be used. In the *best inheritance* heuristic the strategy set Σ_ζ of the best of the randomly chosen ρ parents is used and inherited to all offspring solutions $\zeta = argmax_{i,\ 0 \leq i \leq \rho} f(p_i)$. Self-adaptation is only possible if the strategy variables are modified with the genetic operators. We propose to use Gaussian mutation with step size σ: $\Lambda' = \Lambda + \sigma \cdot \mathcal{N}(0,1)$.

We tested SA-PMX on three TSPs from the TSPlib of Reinelt (1991). For the experiments we use inversion mutation with $p_m = 0.1$, crossover probability of $p_c = 1.0$, population size 100, and fitness proportional parent selection. PMX is the standard PMX with randomized crossover points, SA-PMX is the self-adaptive variant.

	best	avg	dev	worst
ulsysses16				
PMX	6859.0	6866.8	10.6	6950.0
SA-PMX	**6859.0**	**6864.3**	**6.29**	**6875.0**
berlin52				
PMX	**7642.1**	8366.4	270.9	9297.6
SA-PMX	7777.3	**8304.2**	**249.5**	**8921.0**
bier127				
PMX	**123765.0**	133600.4	**3399.7**	141157.7
SA-PMX	125620.9	**133594.2**	3426.5	**140236.1**

Table 1: Analysis of standard PMX and two SA-PMX variants on 3 TSP instances (tourlength).

On TSP instance *ulysses16* [$\sigma = 3$, termination after 500 generations] all variants reached the optimum in the best run, but SA-PMX achieved the best average and worst result with the lowest standard deviation. On problem *berlin52* [$\sigma = 5$, termination after 2000 generations] PMX achieved the shortest but not optimal tour length of all runs, but again SA-PMX succeeded considering the average and the worst tour. On *bier127* [$\sigma = 25$, termination after 3000 generations] again standard PMX attained the best overall tourlength, while SA-PMX achieved a better average and better worst tour.

To summarize the experimental results, a slight but not statistically significant improvement can be reported with self-adaptation of crossover points. An analysis of the development of the crossover points during the runs revealed that they do not converge, but phases can be observed, in which the crossover points move constantly into one direction. The question stays open, whether we can derive from these observations that a meaningful adaptation of crossover points occurs and building blocks can be identified. In particular, we see the challenge to tighten the link between strategy parameter adaptation and fitness gain as we hold an undersized link responsible for the shortcomings in comparison to mutation strength self-adaptation.

3. REFERENCES

[1] D. E. Goldberg and R. Lingle. Alleles, loci and the traveling salesman problem. pages 154–159, 1985.

[2] S. Meyer-Nieberg and H.-G. Beyer. Self-adaptation in evolutionary algorithms. Springer, Berlin, 2007.

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