New Subtour-Based Crossover Operator for the TSP

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Genetic algorithm (GA) is a very useful method for the global search of large search space and has been applied to various problems. It has two kinds of important search mechanisms, crossover and mutation. Because the performance of GA depends on these operators, a large number of operators have been developed for improving the performance of GA. Especially many researchers have more interested in crossover operator than mutation operator because crossover operator has charge of the responsibility of local search. We only deal with crossover operator.

In this paper we propose subtour preservation crossover (SPX), which uses a similar subtour enumeration method to other subtour-based crossovers but has an amount of difference in method that generates a valid tour. SPX generates offsprings as many as we wish by using genetic information of parents propagated over a lot of generations.

And the most severe drawback of subtour-based crossovers is they cannot generate a different offspring when two identical parents are selected for crossover. At our experiments, in case of over 200 generations, the average number of times which two identical parents are selected is over 20. That is, it shows the identical parents are selected about over 30% for total crossovers (Pc = 0.6). So if we do not consider a supplementary method for avoiding this problem, the improvement of solutions will be more and more difficult because crossover operator cannot generate new offspring.

So our method for generating new offspring is as follows. If identical parents are selected in SPX, it first generates two solutions randomly and then applies a local search method to each solution for competing with good solution existing already in population.

Figure 1 indicates the procedure of SPX. The first step of SPX is to enumerate common subtours and then reconnect each subtour using reconnection rule. Reconnection rule is as follow.

(1) Select shorter one between two alternative edges shown in parents.
(2) If shorter edge was already selected, another edge is selected.
(3) If the selected edge has the length of subtour more than 1, all elements included in the subtour are connected in turn.
(4) If both edges were already selected at previous step, random selection is performed among endpoints not selected at previous step.
(5) If all subtours are connected, reconnection procedure is terminated.

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Procedure of Subtour Preservation Crossover
Begin
Set the number of offspring ($Num\_Of\_Offspring$)
Enumerate all common subtours;
$Counter\_Offspring = 0$;
while $Counter\_Offspring$!= $Num\_Of\_Offspring$ **do**
$Counter\_Offspring = Counter\_Offspring + 1$;
Choose an arbitrary starting city (C_i) among endpoints of subtours or cities, which do not construct subtour;
if the number of subtour = 1 **then**
Generate arbitrarily two new offspring;
Apply a local search method to new offspring;
else
while termination condition (complete tour) != yes **do**
Find the adjacent cities (C_j .....C_k) of the city (C_i) in two parents;
if common subtour (S_{it}) exists = yes **then**
$C_i := C_t$;
else
Compare the distances (d_{ij}.....d_{ik}) and find the shortest edge,
$d_{it} = \min(d_{ij},.....,d_{ik})$; $C_i := C_t$;
end
end
end

Fig. 1. Subtour Preservation Crossover (SPX)

Finally we compared the proposed operator to several crossover operators for traveling salesman problem (TSP) for showing the performance of proposed crossover and introduced an efficient simple hybrid genetic algorithm using proposed operator.

From an experiment, we showed SPX to appear the features corresponding to "schema theorem" and "building block hypothesis" and pointed out the necessity of a supplementary method in subtour-based crossovers. By means of several computational experiments, it has been confirmed that SPX can get much better results than permutation based crossovers and other crossover operators using parental information. And a hybrid GA was also implemented by combining 2-opt, nearest neighbor algorithm and SPX. Though HGA was not fine-tuned, it indicated very encouraging results below 3% over the optimum in all test cases (the number of cities is from 100 to 1002).