Simplicity can meet efficiency — The case of the TSP

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Through statistical analysis of experimental results, we have acquired a certain amount of knowledge on the structure of the search space of the TSP involved by the use of 2-change and 3-change operators [FRPT99]. Among other things, local optima are gathered in a tiny region in the case of euclidian 2D TSP instances (a region we call a "massif central").

We have used this knowledge to understand the behavior of descent algorithm; we have also been able to better understand genetic algorithms and how their recombination operator can be used the most efficiently. Grounded on this knowledge, we have designed an efficient algorithm which is basically tinkered with known operators, namely 3-change and edge recombination [WSF89]. On a set of instances of the Tsplib [Rei91], we obtain much better optima than various algorithms based on 3-change, or lk-change published in [JRR95]. This shows very clearly that a careful combination of simple operators is able to find excellent local optima.

Our algorithm works as follows: first, it finds a set of local optima, that is a set of points located on the border of the region where local optima are concentrated; then, we basically interpolate these local optima to progress further and come closer to shorter and shorter tours. In a first time, interpolation has been done by a recombination operator which carefully avoids escaping from the massif central. This algorithm is very efficient for instances of size less than 1000 cities but scales rather poorly above. A second way to interpolate local optima has been designed that basically relies on path relinking ideas: from one local optimum, we build a path towards an other one, or two other local optima. This path is likely to get close to better local optima; performing descent walks from the points along the path between local optima actually provides even better local optima. This algorithm provides even better local optima than the one based on edge recombination. Furthermore, this algorithm scales nicely on instances larger than 1000 cities.

This work can be adapted to other $\mathcal{NP}$-hard problems as long as local optima are concentrated. In particular, we have found for a certain class of instances of the Quadratic Assignment Problem (originating from the Qaplib [BKR97]) that local optima are concentrated into one or several massif centrals. We are on our way to adapt the algorithms we designed for the TSP to these instances.

References

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