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SCANNING-AREA ALGORITHMS FOR CLUSTERED TSP

One of the base problems of combinatorial optimization, that has wide applications, is the Traveling Salesman Problem (TSP). Rapid growth of its size (thousands of points) is the main feature now, and many extensions of this problem with specific properties are studied: dynamic vehicle routing problems; systems with call (the first-aid, the courier's, the taxi), systems with time windows, and systems of delivery. They need development of the special algorithms, which provide high-quality solutions in reasonable time. That is why subsequent perfection of existing algorithms and development of new ones is relevant. In this paper, a set of strategies were proposed and evaluated, in order to solve specific TSP problems in which the points are under the form of clusters.

1. Introduction

In the classic formulation the set N with n ($|N|=n$) points is given, which are described by their coordinates (x_i, y_i). It is necessary to find a route S^*, that passes once through every point with minimal length $L^* = \Sigma_{ij}\, l_{ij}^* \rightarrow min\, \Sigma_{ij}\, l_{ij}$ of the possible by given constraints route between two points i and j. The partial case will be examined with group-concentrated distribution of points that forms the set of k clusters $C = C_1,\ldots,C_k$. The problem is divided into three stages:

1) Every cluster is described by its set of points. For every cluster the shortest route search problem between two edge points α and β is solved (α and β are related to two its adjacent clusters).

2) Finding the initial solution. The initial route is determined, as a concatenation of routes between clusters and routes in all clusters.

3) Route optimization. Optimization of the route is implemented iteratively by optimization of length of paths on separate areas and on the whole. There are two types of optimization:

a) Local optimization on the separate areas of path in cluster.

b) Global optimization by the iterative revision of the whole route.

Let's consider in detail the most essential features of the developed approach.

2. Finding the initial solution

Moving around all adjacent clusters and joining up their solutions, we will get a complete route. Separate task is the TSP for every cluster, where two edge points are given. Initial and eventual points can be determined by different criteria, such as the nearest points of the neighbor clusters. For this purpose the method of "gold edge" was applied. Having initial and eventual points, we connect them by an edge length of which we set artificially by a very small value. Then a good basic (effective and efficient) well-known TSP algorithm is used to solve the problem for every cluster. Thus the set edge will remain in the resulting route and we need only to cut it. We will get an open cycle, which will be part of the full solution (Fig. 1).

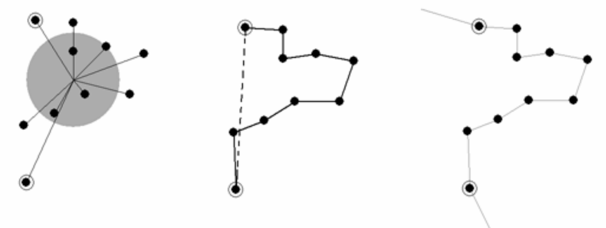

Fig. 1 Determination of edge points in cluster

Having the solutions in every cluster and order of visiting the clusters, it is possible to create the full route. We connect the last point of current cluster with the first point of the next cluster and so on for all routes (Fig.2).

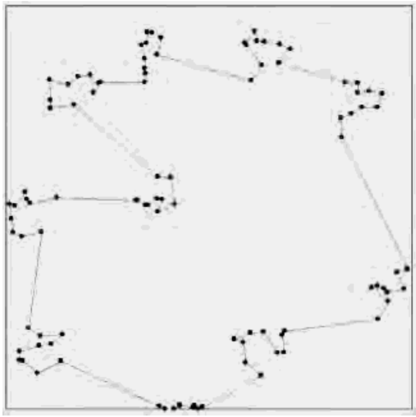

Fig. 2. Union of the partial solutions

Identification of the initial and eventual points (edge points) of every cluster is the important sub-problem. The simplest method of identification of these points is the choice of nearest points of the adjacent clusters. However, an optimal route not always includes transition from one cluster to another only by the nearest points. In some cases, it is possible that the length of the route in a cluster will decrease if some other point, not nearest to the adjacent cluster, is chosen. Fig. 3 shows the example of such situation. The choice of edge point as the nearest points between the adjacent clusters is represented on the left. Choice of other point as an edge point decreases the length of route.

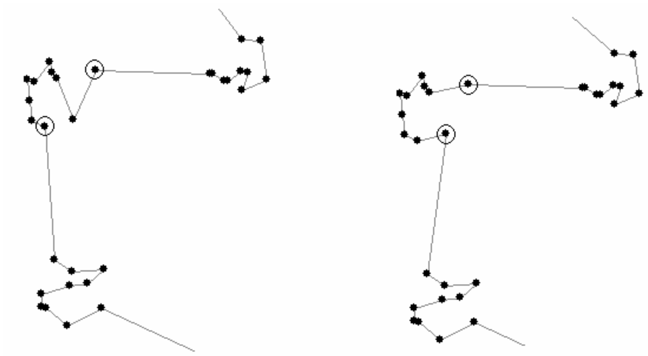

Fig. 3. The choice of nearest points of adjacent clusters affects the result

The spectrum of strategies for search of the edge points in a cluster and creation of complete route was investigated. We describe basic strategies.

3. Scanning area algorithms

Two main strategies of scanning area, called ESA1 and ESA2 are presented below.

Strategy ESA1 (Elementary Scanning Area 1).

The elementary scanning area includes a cluster and an edge point of the next cluster (Fig. 4).

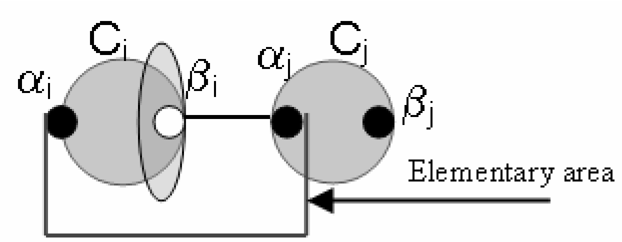

Fig. 4. Elementary scanning area of strategy ESA1

The given strategy has a few variants. First one: visiting of all clusters from first one to the last (clockwise direction), setting the eventual point of every current cluster and use it as fixed in scanning of the next cluster (algorithm ESA1-L).

- Second: visiting of all clusters in other direction - from the last to the first (anticlockwise direction), and then the initial point of every cluster will be unfixed (algorithm ESA1-R).

- The third approach is combination of the first and second approaches - we walk around every cluster in one direction, and then in another. Thus every cluster will be scanned twice (algorithm ESA1-LR). Fig. 5 represents these three algorithms.

Strategy ESA1 is the simplest and economic procedure of scanning. Only the one point comparatively with the size of cluster increases the scanning area size. However here only half of edge points are examined as unfixed. Approach ESA1-LR foresees scanning of every elementary region twice, it requires twice more of computational time, however higher solution quality is provided, as every edge point of every cluster is examined as unfixed.

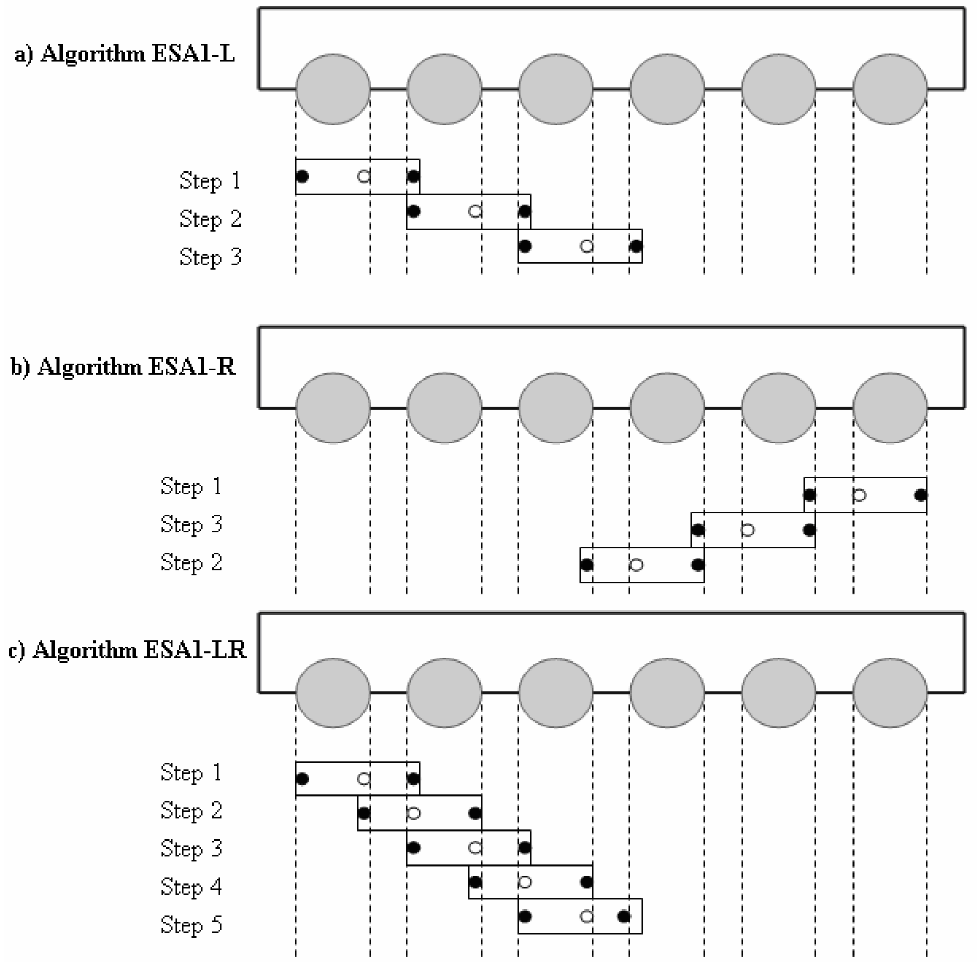

Fig. 5. Strategy ESA1

Strategy ESA2 (Elementary Scanning Area 2).

The cluster and edge points of two neighboring clusters create an elementary scanning area (ESA2).

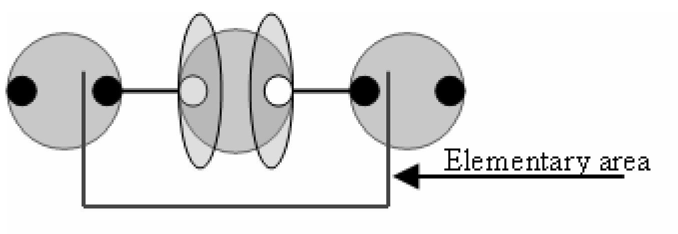

Fig. 6. Elementary area of strategy ESA2

The given strategy has two variants (Fig. 7).

- First one - scanning of every cluster in turn and determination unfixed edge points (EAS2-1).
- Second strategy - even clusters are scanning in the first order and then odd clusters in the second order (EAS2-2).

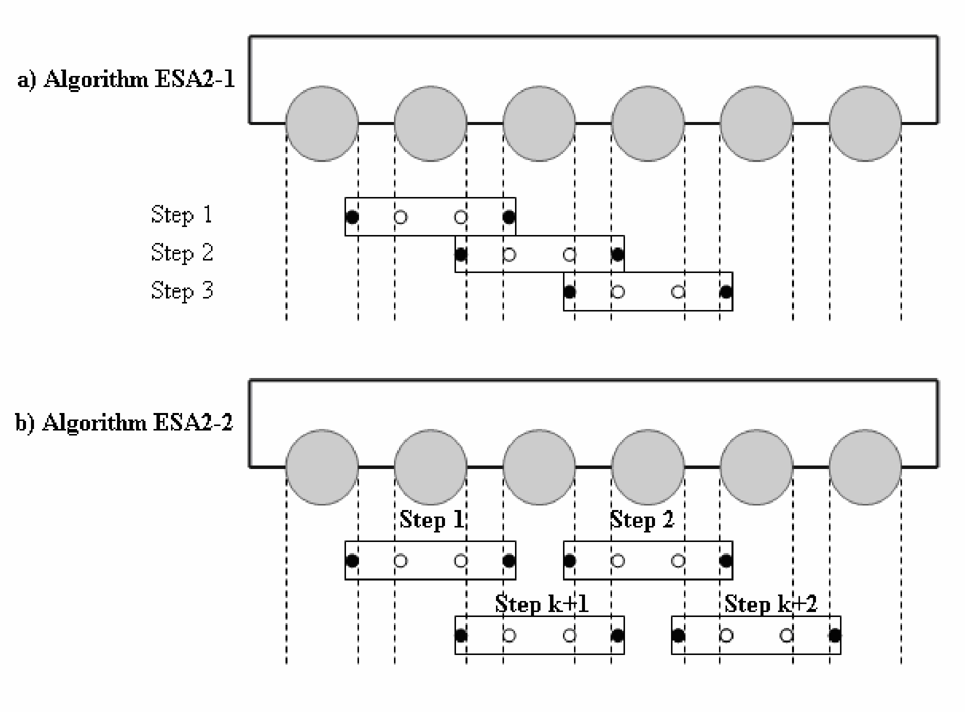

Fig. 7. Strategy ESA2

4. Experiments

Five tests of 10000 points and one test of 75000 points were generated. For each test the size of cluster was fixed - 10 points. The results of the route determination were compared to the results of the base algorithm - 2-opt. All tests run on PC with a processor Pentium IV - 3000 MHz with 512 Mb RAM. Fig. 8 and Fig. 9 shows the experimental results for the problems with 10000 and 75000 points respectively.

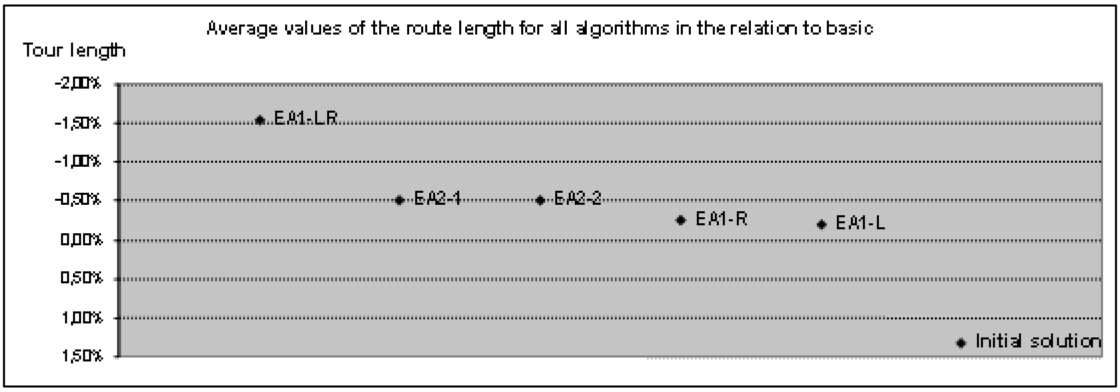

Fig. 8. Results for the problem with the 10000 points

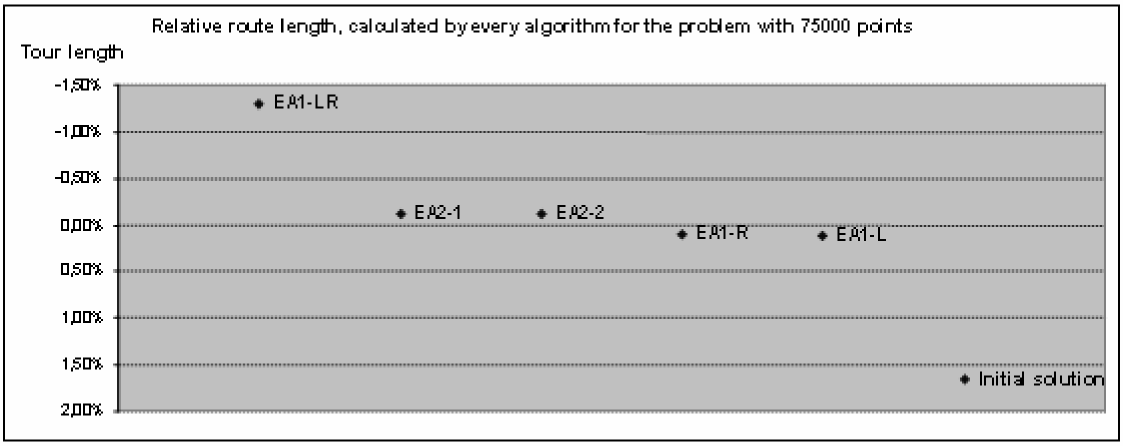

Fig. 9. Results for the problem with 75000 points

5. Conclusion

Scanning area algorithms allow substantially decreasing computational time of TSP, especially in the large-scale problems. The strategy ESA1-LR demonstrates the improvement of quality compared with a base algorithm and near 3% improvement with the initial solution.

References

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