PACE Challenge 2024: KongQi Heuristic Solver Description

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Abstract

One-sided crossing minimization problem involves arranging the nodes of a bipartite graph on two layers,with one of the layers fixed,aiming to minimize the number of edge crossings.In this paper, we introduce the intersection matrix and a local search algorithm to solve this problem. The crossing matrix calculates the number of intersections between every pair of nodes. The local search algorithm uses a classic meta-heuristic algorithm framework and insertion-based neighbor move operation.

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1 Heuristic Solver Description

The input of the one-sided crossing minimization problem is a bipartite graph $G = ((A \cup B), E)$ and a fixed linear order of A.The output is a linear ordering of B.The goal is to minimize the number of edge crossings between A and B. For the sake of convenience, we define $n = |A|, m = |B|, k = |E|$. We use o to denote the order of nodes in B, where o_i represents the i_{th} node in the order.

2 Local Search

We design a neighborhood based on insertion.For a pair of nodes i and j, $\eta(i, j)$ represents inserting node i right after node j if node i precedes node j,or inserting node i right before node j if node j precedes node i.

2.1 Crossing Matrix

The crossing matrix is a matrix that records the number of crosses between every pair of nodes.We define CM to be the crossing matrix and CM_{ij} to be the number of crosses between node i and noded j when node i precedes node j,i.e.,$o_i < o_j$.

2.2 Incremental Evaluation of Neighborhood Moves

Calculating the objective value of each neighboring solution is the most time-consuming part in local search.Therefore,the performance could usually be improved by recording useful information and incrementally evaluating the neighborhood moves.Then,the objective improvement of swapping a pair of adjacent nodes i and j can be calculated by $\delta(\eta(i, j)) = (CM_{ij} - CM_{ji})$.With the crossing matrix CM_{ij},it is not necessary to calculate the total cross number from scrath,instead,the new objective value after an insertion can be incrementally

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calculated based on the original solution.Specifically,given a solution X,the improvement of the objective value of an insertion move $\delta(\eta(i,j))$ can be recursively calculated according to following equation:

$$\delta(\eta(i,j)) = \begin{cases} \delta(\eta(i,pre(j))) - CM_{ij} + CM_{ji} & o_i < o_j \\ 0 & o_i = o_j \\ \delta(\eta(i,suc(j))) + CM_{ij} - CM_{ji} & o_i > o_j \end{cases}$$

where the utility functions $pre(i)$ and $suc(i)$ represent the predecessor and successor of node i,respectively,i.e.,$o_{pre(i)} = o_i - 1$ and $o_{suc(i)} = o_i + 1$.A long-span insertion $\eta(i,j)$ can be decomposed into a shorter insertion $\eta(i,pre(j))$ and an insertion $\eta(pre(j),j)$ that only involves a pair of adjacent nodes.

3 Perturbation Operator

When the search stagnates,a perturbation for escaping the local optima will be applied.This is achieved by randomly picking 20% new nodes and inserting them into random positions.

References

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