Assignment 9 - Hybrid evolutionary algorithm

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Description of the problem

The travelling salesman problem (TSP) is a classic optimization problem. Given a list of cities and the distances between them, the task is to find the shortest possible route that visits each city exactly once and returns to the origin city. In this version of the problem, each city also has a cost of being visited, and we only need to select half of the cities.

As an input we received a list of coordinates of cities, along with the cost. To calculate the distance between cities we used Euclidean distance, and each city is represented as a number from 0 to n-1 (n-number of cities). The objective function is to find the route that minimizes the sum of distances between cities and the cost of visiting them.

Pseudocode of all implemented algorithms

Hybrid evolutionary algorithm

```
Function RunHybridEvolutionary
    Initialize the starting population of 20 individuals (Random starting solution with SteepestDeltasLocalSearch run on each)
    Evaluate each individual in the population
    Sort the population by the fitness

    Until the running time is exceeded:
        Choose parent1 and parent2 from the population at random
        Perform crossover on parent1 and parent2 to create a child
        Perform mutation on the child
        Either run SteepestDeltasLocalSearch on the child or proceed without LS
        If the child already exists in the population go back to the beginning of the loop
        Add the child to the population, sort it and truncate to keep the best 20 individuals

    Return the best individual from the population
```

Mutation operator

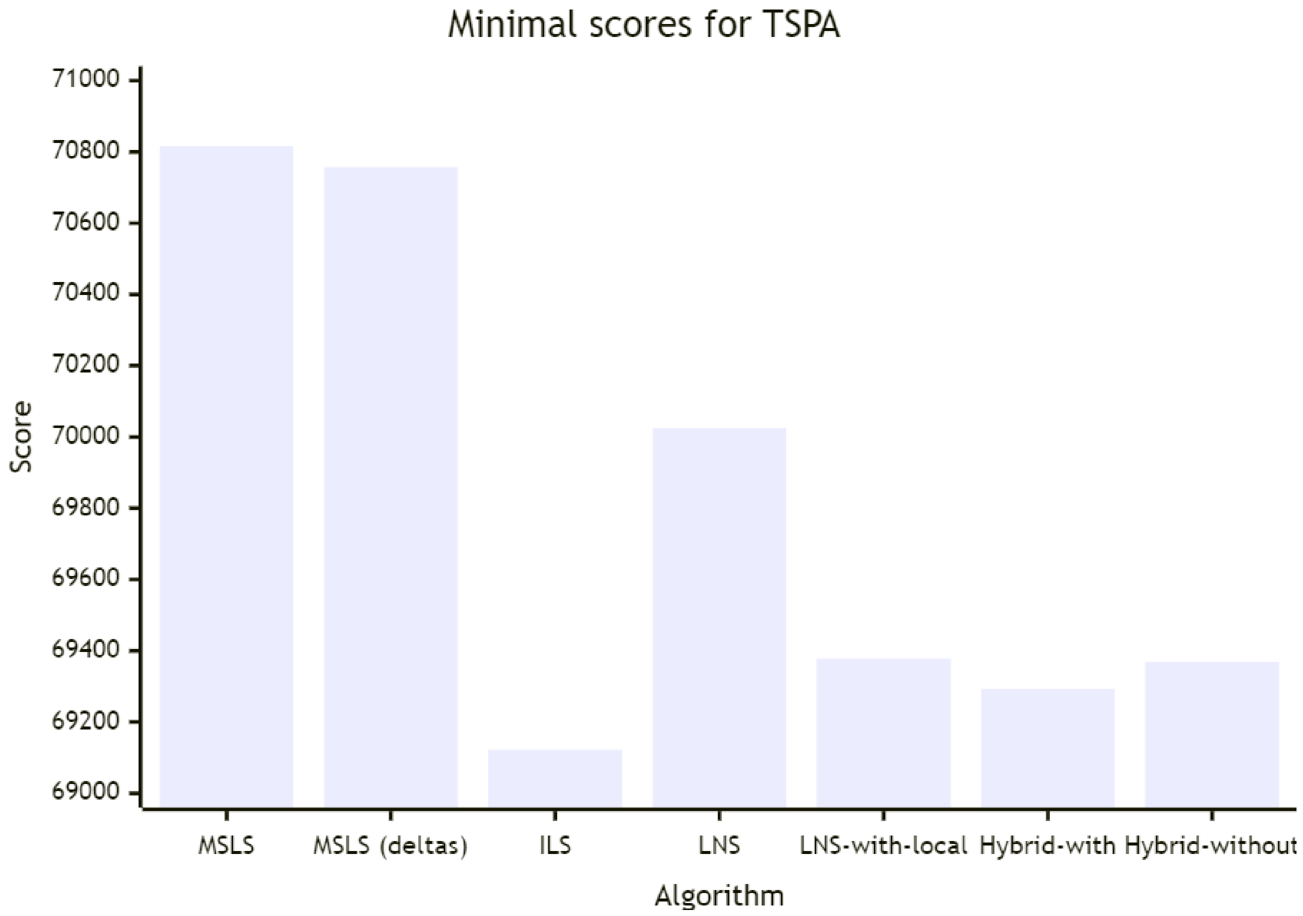
```
Function Mutate
    Choose a random node from the individual to be replaced
    Choose a random node from the remaining nodes to replace it with
    Replace the nodes
    Return the mutated individual
```

Crossover operator

```
Function Crossover
    Input: parent1, parent2
    Create a set of all edges and their counterparts from parent1
    Create an empty set nodes_to_keep
    Iterate through edges of parent2
        If the edge is in the set of edges from parent1 add the nodes forming this edge to nodes_to_keep
    Create a child with the nodes from nodes_to_keep and fill the remaining nodes with the GreedyWeighted2Regret heuristic
    Return the child
```

Table of the results

Algorithm	TSPA	TSPB
Random Start Two Edges Intra Steepest Deltas	74207 (71342-78723)	49160 (46761-52674)
Random Start Two Edges Intra Steepest Multiple Start Local Search	71299 (70817-71812)	45970 (45235-46595)
Random Start Two Edges Intra Steepest Deltas Multiple Start Local Search	71700 (70758-72325)	46101 (45578-46676)
Random Start Two Edges Intra Steepest Deltas Iterated Local Search	69340 (69122-69531)	43647 (43507-43877)
Greedy Regret Heuristic with weighted 2-Regret Random Destroy LNS	70987 (70024-72625)	46034 (44398-48968)
Greedy Regret Heuristic with weighted 2-Regret Random Destroy LNSw	69720 (69378-70168)	44095 (43509-44602)
Hybrid Evolutionary Algorithm with LS after recombination	69831 (69293-70248)	45231 (44659-45867)
Hybrid Evolutionary Algorithm with without LS after recombination	70094 (69369-70618)	45185 (44236-46196)


Minimal scores for TSPA
Score
71000
70800
70600
70400
70200
70000
69800
69600
69400
69200
69000
MSLS
MSLS (deltas)
ILS
LNS
LNS-with-local
Hybrid-with
Hybrid-without
Algorithm

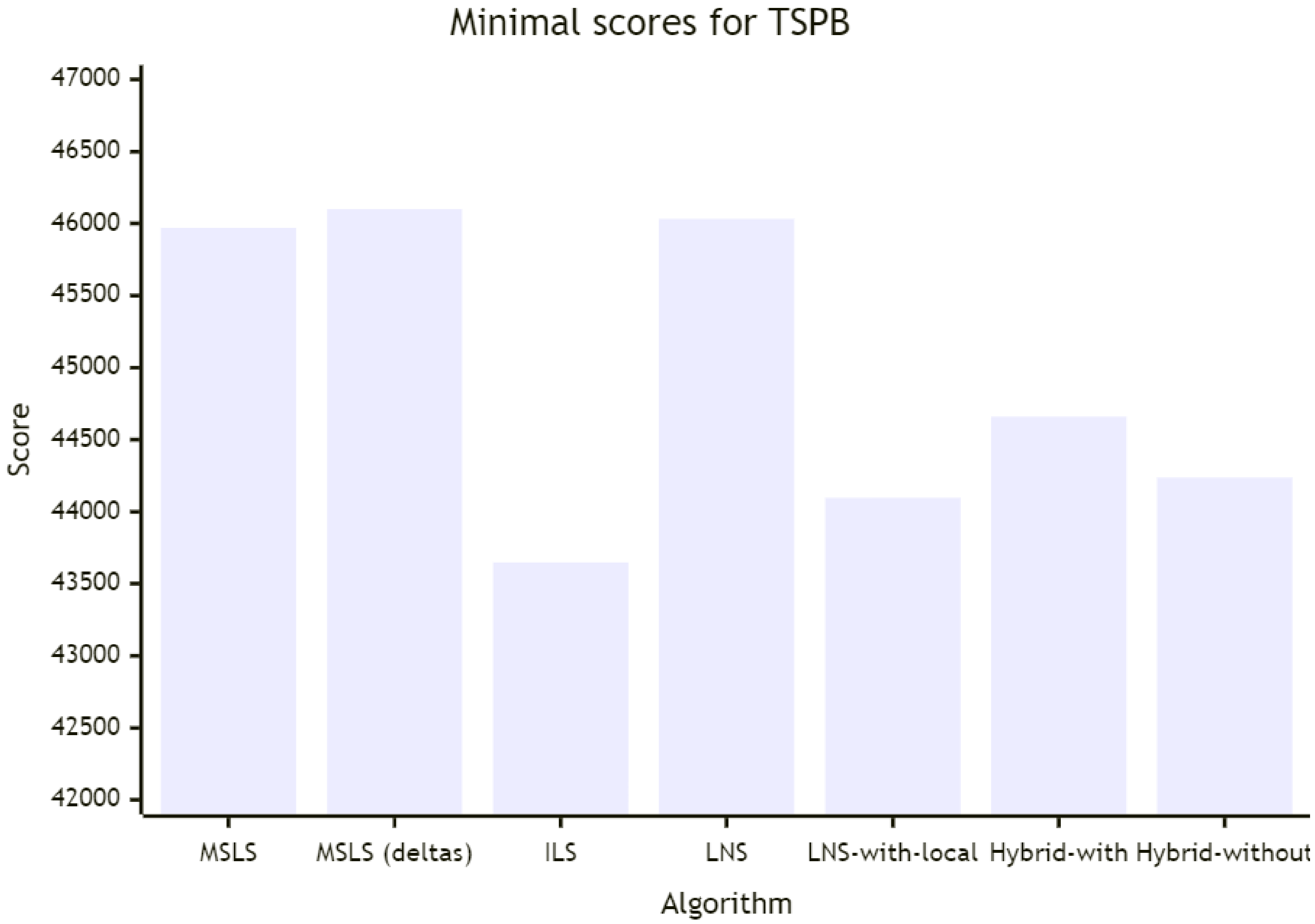

Minimal scores for TSPB
Score
47000
46500
46000
45500
45000
44500
44000
43500
43000
42500
42000
MSLS
MSLS (deltas)
ILS
LNS
LNS-with-local
Hybrid-with
Hybrid-without
Algorithm

Table of average number of main loop iterations

Algorithm	Iterations
Greedy Regret Heuristic with weighted 2-Regret Random Destroy LNS	1183
Greedy Regret Heuristic with weighted 2-Regret Random Destroy LNSw	846
Random Start Two Edges Intra Steepest Multiple Start Local Search	200
Random Start Two Edges Intra Steepest Deltas Multiple Start Local Search	200
Random Start Two Edges Intra Steepest Deltas Iterated Local Search	382
Hybrid Evolutionary Algorithm with LS after recombination	509
Hybrid Evolutionary Algorithm with without LS after recombination	3130

Results of previous algorithms

Algorithm	TSPA	TSPB
Random Algorithm	225467	193417
Nearest Neighbor (Add at End)	83182	52319
Nearest Neighbor (Insert Anywhere)	71179	44417
Greedy Cycle	72636 (71488-74410)	51401 (49001-57324)
Greedy Regret Heuristic with 2-Regret	116681 (108804-123447)	70265 (65043-76325)
Greedy Regret Heuristic with Weighted 2-Regret	72148 (71108-73718)	50997 (47144-56747)
Random Start Two Edges Intra Steepest Candidate	79763 (74876-84144)	51500 (47433-58226)
Random Start Two Edges Intra Steepest	75172 (72784-80372)	49635 (47325-52654)
Random Start Two Nodes Intra Greedy	86727 (82039-95867)	61477 (53396-67230)
Random Start Two Edges Intra Greedy	74035 (77907-82039)	48390 (45665-51760)
Greedy Start Two Nodes Intra Greedy	71599 (70602-72778)	45331 (43826-51911)
Greedy Start Two Edges Intra Greedy	71335 (70004-72452)	44898 (43790-50892)
Random Start Two Nodes Intra Steepest	88618 (81178-98102)	63387 (56112-73195)
Greedy Start Two Nodes Intra Steepest	71936 (71041-73353)	45355 (43862-51147)
Greedy Start Two Edges Intra Steepest	71677 (70397-72984)	45008 (43958-50901)
Random Start Two Edges Intra Steepest Candidate	79763 (74876-84144)	51500 (47433-58226)
Random Start Two Edges Intra Steepest	75326 (72938-80126)	49725 (46957-52832)

Raw results

TSPA

```
Results for Steepest Deltas Random Replace Mutation Keep Common Fill LS Crossover
with Greedy Regret Heuristic with weighted 2-Regret Hybrid Evolutionary algorithm
Min cost: 69293
Max cost: 70248
Average cost: 69831

Time took for 20 runs: 40.04714160s, time per run: 2002357µs

Best solution:
[118, 51, 151, 133, 162, 123, 127, 70, 135, 154, 180, 53, 121, 100, 26, 86, 75,
101, 1, 97, 152, 2, 129, 57, 92, 82, 120, 44, 25, 16, 171, 175, 113, 56, 31, 78,
145, 179, 196, 81, 90, 165, 40, 185, 55, 52, 106, 178, 49, 14, 144, 102, 62, 9,
148, 124, 94, 63, 79, 80, 176, 137, 23, 186, 89, 183, 143, 0, 117, 93, 140, 68,
46, 115, 139, 41, 193, 159, 69, 108, 18, 22, 146, 181, 34, 160, 48, 54, 177, 10,
190, 4, 112, 84, 184, 42, 43, 116, 65, 59]

Results for Fake Local Search Random Replace Mutation Keep Common Fill LS
Crossover with Greedy Regret Heuristic with weighted 2-Regret Hybrid Evolutionary
algorithm
Min cost: 69369
Max cost: 70618
Average cost: 70094

Time took for 20 runs: 40.03158410s, time per run: 2001579µs

Best solution:
[181, 34, 160, 48, 54, 177, 10, 190, 4, 112, 84, 35, 184, 42, 43, 116, 65, 59,
118, 51, 151, 133, 162, 123, 127, 70, 135, 154, 180, 53, 121, 100, 26, 86, 75,
101, 1, 97, 152, 2, 120, 44, 25, 16, 171, 175, 113, 56, 31, 78, 145, 179, 92, 129,
57, 55, 52, 185, 40, 196, 81, 90, 165, 106, 178, 49, 14, 144, 102, 62, 9, 148,
124, 94, 63, 79, 80, 176, 137, 23, 186, 89, 183, 143, 0, 117, 93, 140, 68, 46,
115, 139, 41, 193, 159, 69, 108, 18, 22, 146]
```

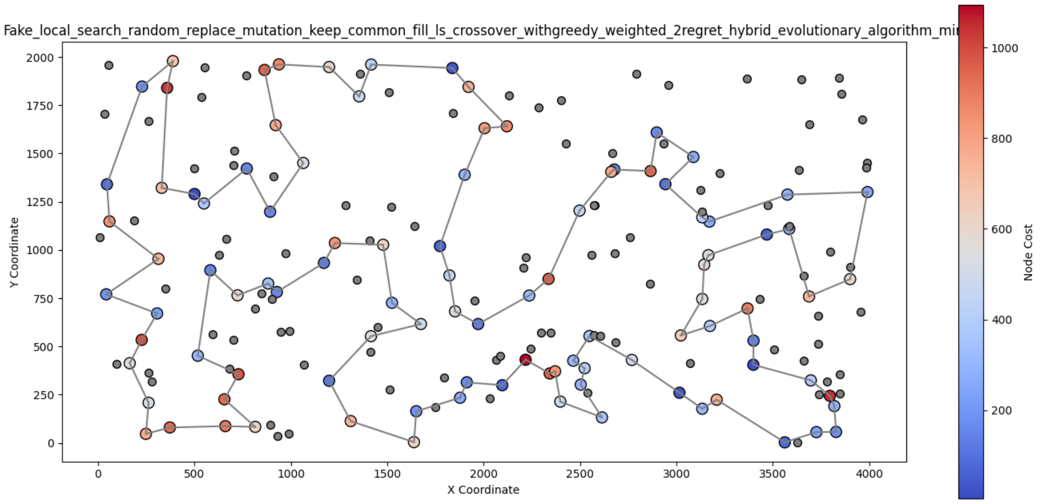
TSPB

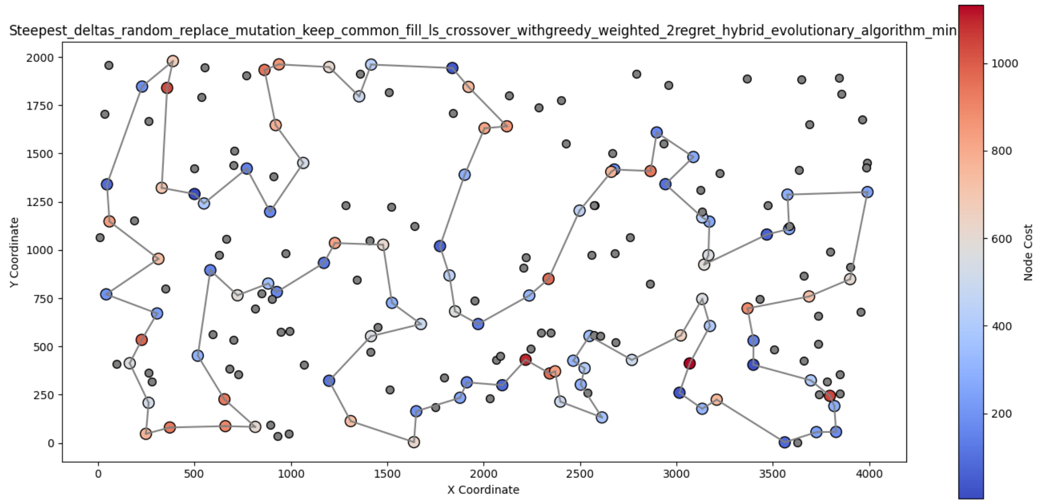
```


Results for Steepest Deltas Random Replace Mutation Keep Common Fill LS Crossover
with Greedy Regret Heuristic with weighted 2-Regret Hybrid Evolutionary algorithm
Min cost: 44659
Max cost: 45867
Average cost: 45231

Time took for 20 runs: 40.06822370s, time per run: 2003411µs

Best solution:
```

```
[38, 27, 16, 1, 24, 156, 198, 117, 193, 31, 54, 73, 136, 190, 80, 45, 175, 78, 5,
177, 25, 104, 8, 111, 82, 21, 61, 36, 91, 141, 77, 81, 153, 187, 163, 89, 127,
103, 113, 176, 194, 166, 86, 95, 130, 99, 185, 179, 172, 57, 66, 94, 47, 148, 60,
20, 59, 28, 149, 4, 140, 183, 152, 170, 34, 55, 18, 62, 124, 106, 143, 35, 109, 0,
29, 160, 33, 138, 11, 139, 43, 168, 195, 145, 15, 3, 70, 13, 132, 169, 188, 6,
147, 90, 51, 121, 131, 122, 135, 63]

Results for Fake Local Search Random Replace Mutation Keep Common Fill LS
Crossover with Greedy Regret Heuristic with weighted 2-Regret Hybrid Evolutionary
algorithm
Min cost: 44236
Max cost: 46196
Average cost: 45185

Time took for 20 runs: 40.02311780s, time per run: 2001155µs

Best solution:
[28, 149, 4, 140, 183, 152, 170, 34, 55, 18, 62, 128, 124, 106, 143, 35, 109, 0,
29, 160, 33, 138, 11, 139, 43, 168, 195, 145, 15, 3, 70, 13, 132, 169, 188, 6,
147, 71, 51, 121, 131, 90, 122, 133, 107, 40, 63, 135, 38, 27, 16, 1, 156, 198,
117, 193, 54, 31, 73, 136, 190, 80, 162, 175, 78, 5, 177, 104, 8, 82, 21, 36, 61,
91, 141, 77, 81, 153, 187, 163, 89, 127, 103, 113, 176, 194, 166, 86, 185, 95,
130, 99, 22, 179, 66, 94, 47, 148, 60, 20]
```

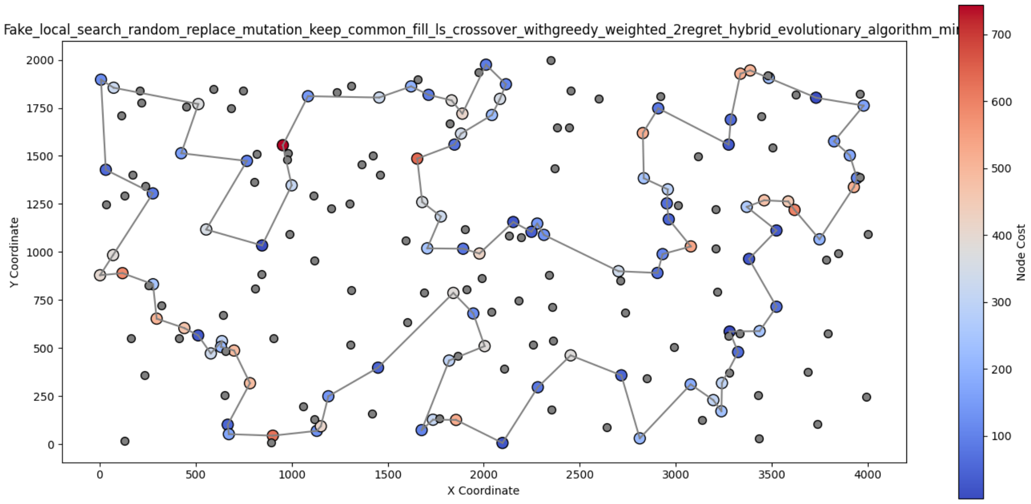
Plots of the results

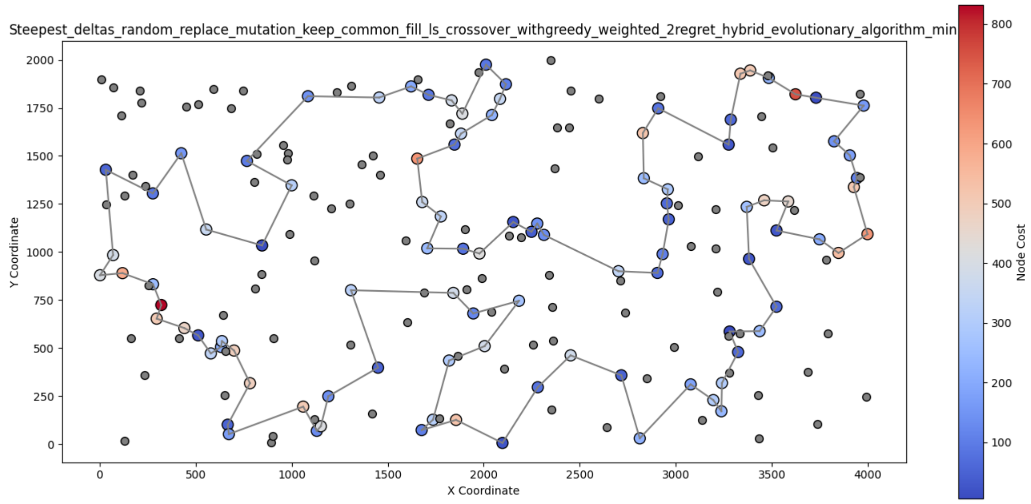
TSPA


Fake_local_search_random_replace_mutation_keep_common_fill_ls_crossover_withgreedy_weighted_2regret_hybrid_evolutionary_algorithm_mi
Y Coordinate
X Coordinate
0
250
500
750
1000
1250
1500
1750
2000
0
500
1000
1500
2000
2500
3000
3500
4000
Node Cost
200
400
600
800
1000


Steepest_deltas_random_replace_mutation_keep_common_fill_ls_crossover_withgreedy_weighted_2regret_hybrid_evolutionary_algorithm_min
Y Coordinate
X Coordinate
0
250
500
750
1000
1250
1500
1750
2000
0
500
1000
1500
2000
2500
3000
3500
4000
Node Cost
200
400
600
800
1000

TSPB





Source code

- Github repository

Conclusions

The hybrid evolutionary algorithm performed better than Multiple Start Local Search and Large Neighborhood Search, but slightly worse than Iterated Local Search. The number of iterations of HEA without LS was significantly higher than HEA with LS, also HEA without LS had the highest number of iterations in general among all previous algorithms. The performance of HEA with and without LS varied across instances, sometimes one outperformed the other.