Assignment 10: Own Method (Cluster-based Initial Solutions)

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Source code:
https://github.com/MatTheTab/Evolutionary-Computation/blob/main/Assignment%2010%20Own%20Method/Assignment_10_MSLS_ILS.ipynb

1. Description of the Problem

During the semester, various characteristics of a well performing algorithm were made clear. In this report we will try to improve the already best-performing algorithm found (ILS with random shuffle of 20% of consecutive nodes) by providing a better initial solution to begin searching. As previously, the task is to find a cycle composed of half of all available nodes with the smallest value of the objective function, with the function defined as the sum of the length of the cycle and the weight/cost of every node in the cycle. The visualizations related to the redefined TSP for both available instances TSPA and TSPB can be found in Figure 1 and Figure 2.

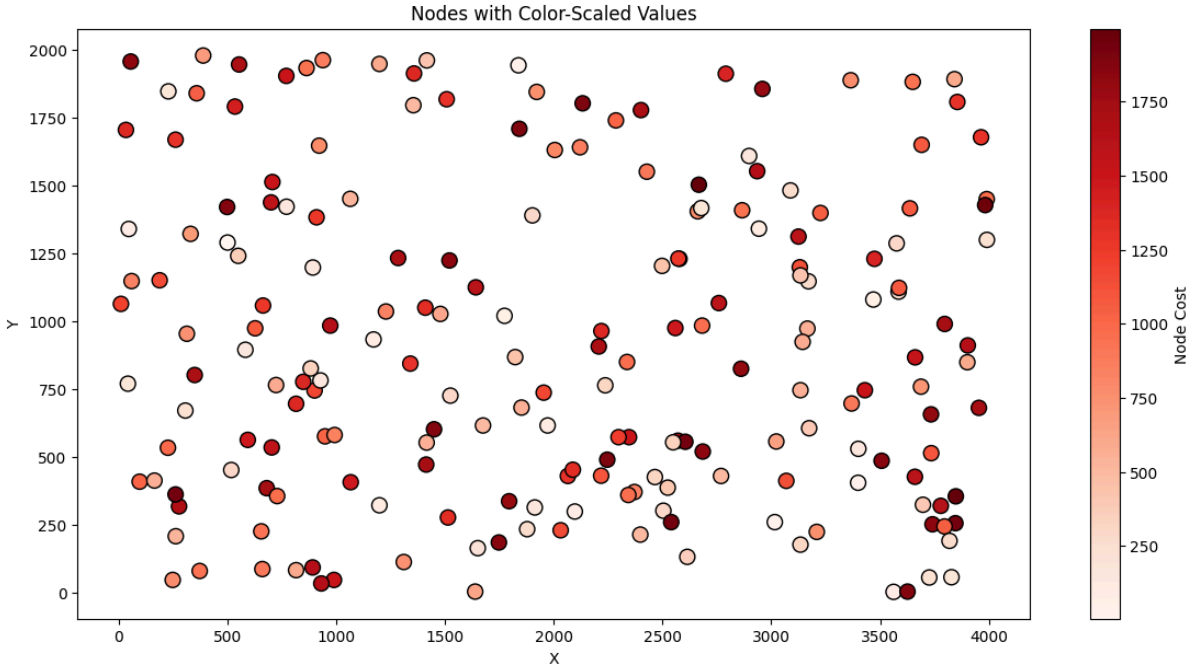

Fig 1. Visualization of the TSPA problem instance, each node's x and y locations on the plot correspond to their given x and y locations and the color intensity signifies the weight/cost of each node. The total length of the cycle and the sum of node weights should be minimized.

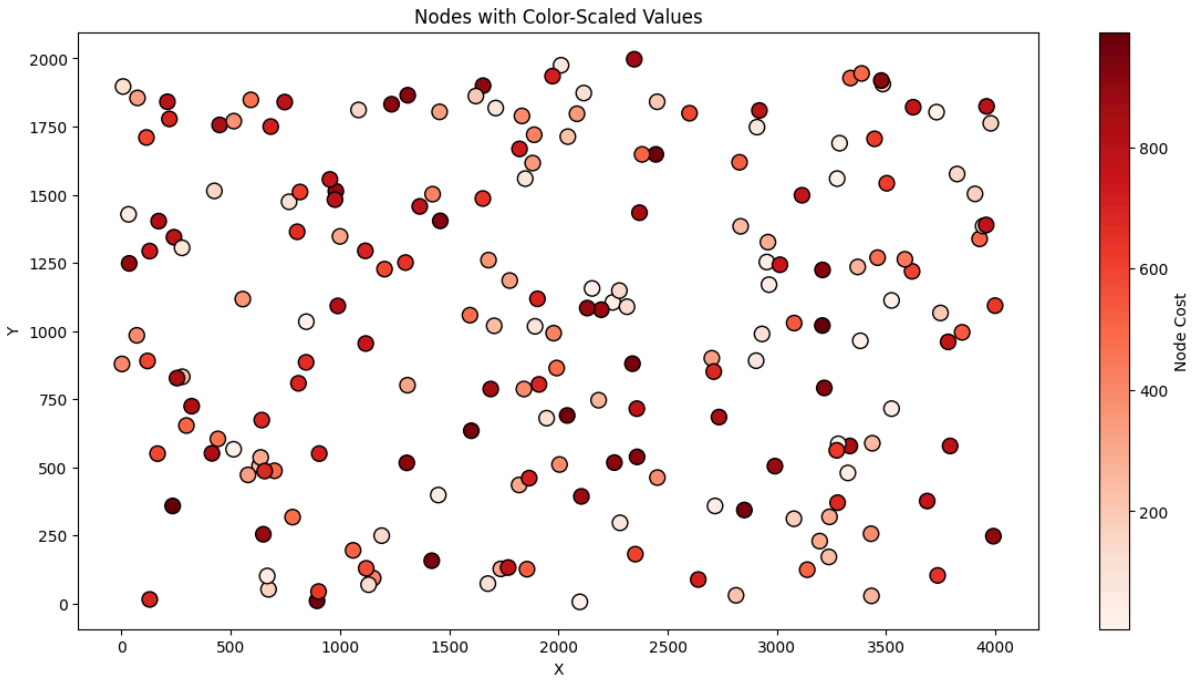

Fig 2. Visualization of the TSPB problem instance, each node's x and y locations on the plot correspond to their given x and y locations and the color intensity signifies the weight/cost of each node. The total length of the cycle and the sum of node weights should be minimized.

2. Algorithms

It became apparent in previous attempts of solving the aforementioned problems that the algorithms which are able to find the best solutions very often favor low-weight nodes heavily. However, as was made clear by additional tests performed, providing only a random permutation of the lowest weight nodes or a local optimum solution on the lowest weight nodes as the initial solution in the ILS algorithm did not manage to outperform the results obtained with providing a random solution from all of the nodes. This is likely due to the fact that selecting only the lowest-weight solutions might lead to limiting the initial space of search distance-wise meaning that some good nodes might be left isolated and difficult to reach by the algorithm. Due to this reason we have devised a clustering-based method that first creates 10 clusters using the K-Means algorithm using the coordinates of all nodes as input, then selects 10 lowest-weight nodes from each cluster to be included in the final selection and finally it shuffles the solution before returning it. This way, low weight nodes are selected from sections spanning the entire coordinate space of the problem creating a solution aiding the algorithm in performing improving operations more reliably.

```
FUNCTION cluster_based_selection(distance_matrix, weights, coordinates):

    INPUT:
        distance_matrix - matrix of distances between nodes
        weights - an array of weights associated with each node
        coordinates - an array of x,y coordinates of each node
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num_clusters ← 10
clusters ← KMeans(coordinates, num_clusters)

selected_nodes ← []
FOR cluster IN clusters:
   cluster_indices ← SELECT ALL node indices of nodes belonging to cluster
   cluster_weights ← SELECT ALL weights with cluster_indices
   SORT cluster_indices using cluster_weights
   APPEND to selected_nodes first 10 cluster_indices

SHUFFLE selected_nodes
RETURN selected_nodes, score(selected_nodes)
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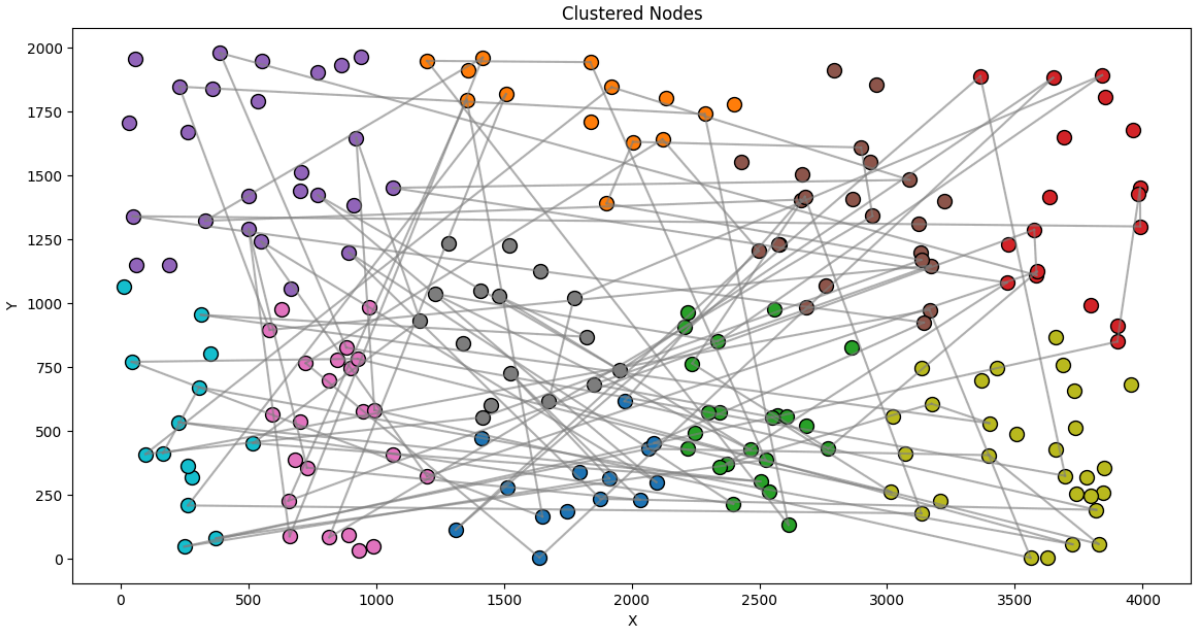

Fig 3. Visualization of an initial solution created by the clustering-based initial solution function on the TSPA instance. Colors of nodes correspond to the distinct clusters.

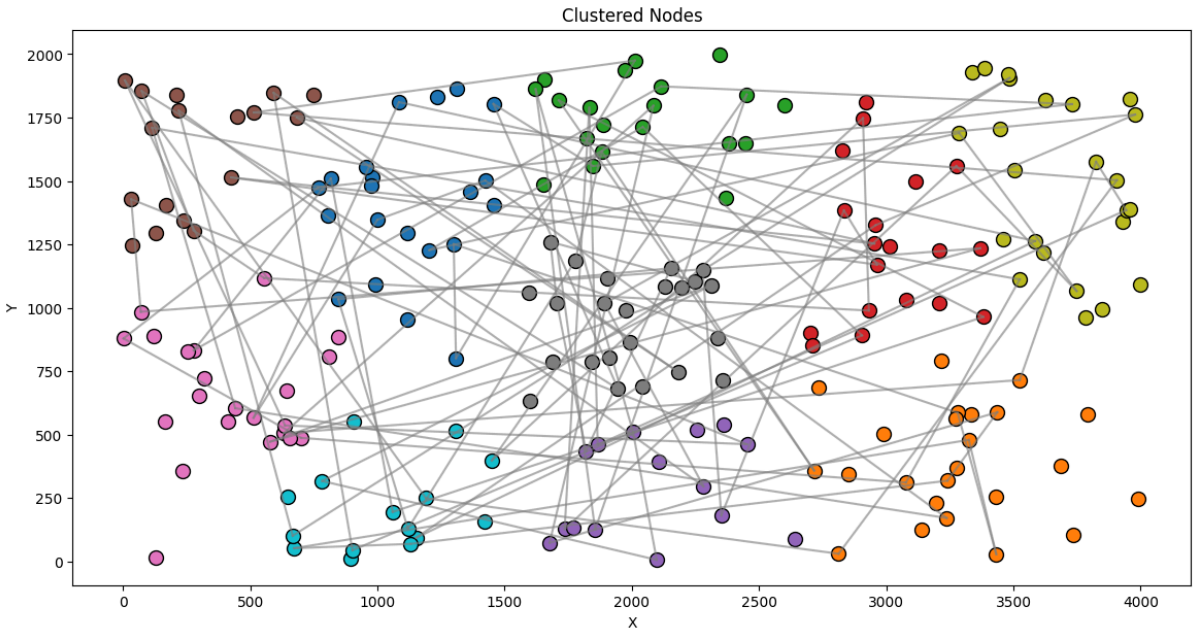

Fig 4. Visualization of an initial solution created by the clustering-based initial solution function on the TSPB instance. Colors of nodes correspond to the distinct clusters.

3. Experiments

Experiments include all previous methods along with the newly created method. For each instance, tests were run in the same way as for the initial ILS/MSLS assignment (20 runs with stopping condition of mean MSLS execution time) with the initial solution algorithm swapped for the new method and the best performing perturbation function found previously (random shuffle of 20% of consecutive nodes). Best previous solutions were moved to the top of the table below.

Method	TSPA av (min - max)	TSPB av (min - max)	Num Iterations (TSPA/TSPB)
ILS - Partial Shuffle + Cluster Initialization	**69383 (69095 - 69720)**	**43835 (43519 - 44493)**	**1407/1430**
Evolutionary (Common + Random Recombination + LS)	69637 (69554 - 69692)	43897 (43811 - 43933)	2494/2104
Large Neighborhood Search (optional LS)	69457 (69207 - 69821)	44133 (43873 - 44463)	387/357
ILS - Partial Shuffle	69545	43952	1548/1495

	(69141 - 70200)	(43448 - 44659)	
Evolutionary (Common + Random Recombination)	74060 (72242 - 76036)	48800 (46931 - 50831)	892080/671469
Evolutionary (Common + Heuristic Recombination + LS)	72396 (71881 - 72708)	47405 (46611 - 48051)	101/82
Evolutionary (Common + Heuristic Recombination)	73600 (72050 - 75872)	48566 (47111 - 50888)	445/276
Evolutionary (ERX Recombination + LS)	70393 (69761 - 70635)	44757 (44287 - 44981)	190/200
Evolutionary (ERX Recombination)	74196 (73113 - 76574)	47880 (46856 - 48519)	59939/55978
Large Neighborhood Search (no LS)	69640 (69250 - 70805)	44361 (44174 - 44657)	403/391
MSLS	71340 (70919-71756)	45952 (45365-46428)	200/200
Weighted Greedy Regret Cycle	72133 (71108-73395)	50882 (47144-55700)	
Steepest Delta Search	73910 (71118-78710)	48574 (46300-51342)	-
ILS - MST Perturbation	70133 (69246 - 71271)	44360 (43658 - 45019)	1582/1525
ILS - Coordinate Change	69882 (69460 - 70419)	44201 (43574 - 44853)	315/345
Steepest Candidate Search	77944 (73159-84951)	48497 (45342-52178)	-
Greedy LS Rand	85812 (78831-93289)	61000 (53759-69662)	-
Steepest LS Rand	87935 (75935-95175)	63036 (55323-70187)	-

Greedy LS Edges Rand	73781 (71507-76491)	48427 (45646-51763)	-
Steepest LS Edges Rand	73954 (70948-77934)	48366 (45576-51616)	-
Greedy LS Best	71627 (70687-72882)	45460 (43826-51301)	-
Steepest LS Best	71619 (70626-72950)	45415 (43826-50876)	-
Greedy LS Edges Best	71515 (70571-72460)	45040 (43790-50495)	-
Steepest LS Edges Best	71468 (70510-72614)	44976 (43921-50495)	-
Random	264301 (223539-308435)	213397 (179796-253866)	-
Nearest Neighbor Closest	85109 (83182-89433)	54390 (52319-59030)	-
Nearest Neighbor All	73180 (71179-75450)	45870 (44417-53438)	-
Greedy Cycle	72606 (71488-74350)	51345 (48765-57262)	-
Greedy Regret Cycle	115630 (105852-123171)	72656 (67568-77329)	-

Table 1. Minimum, average, and maximum scores achieved by each method on both problem instances.

The **best scores achieved** are visualized below.

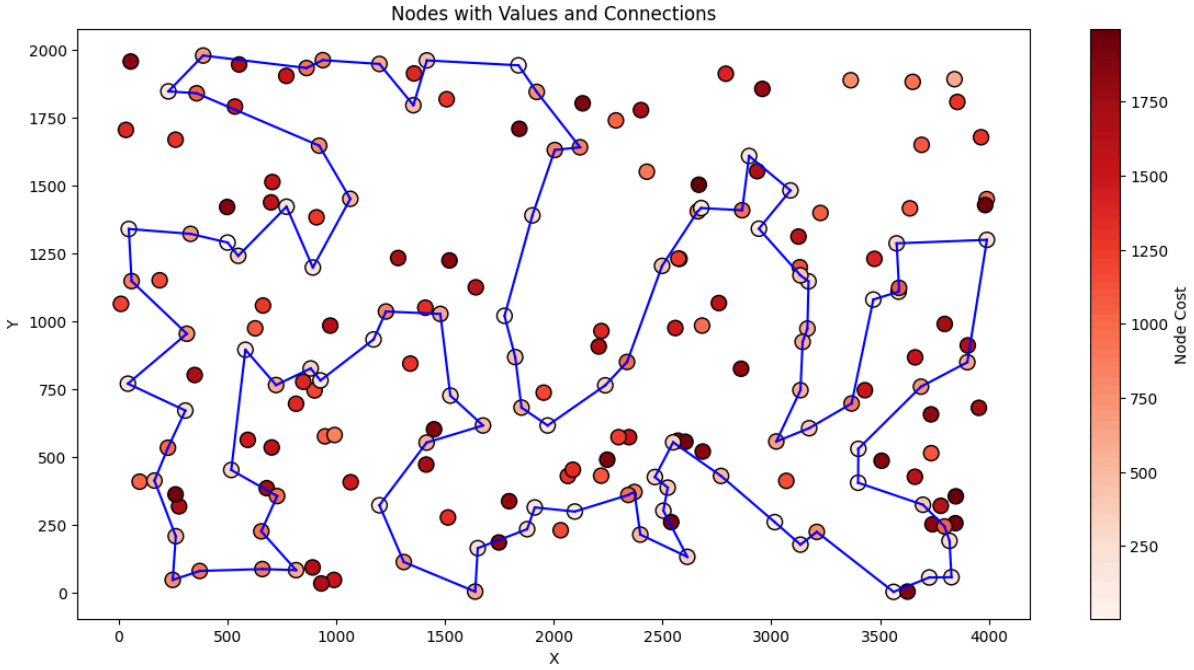

Fig 5. Visualization of the best solution found by the **ILS Random Shuffle (20%) with clustering-based initial solution function** on the TSPA instance.

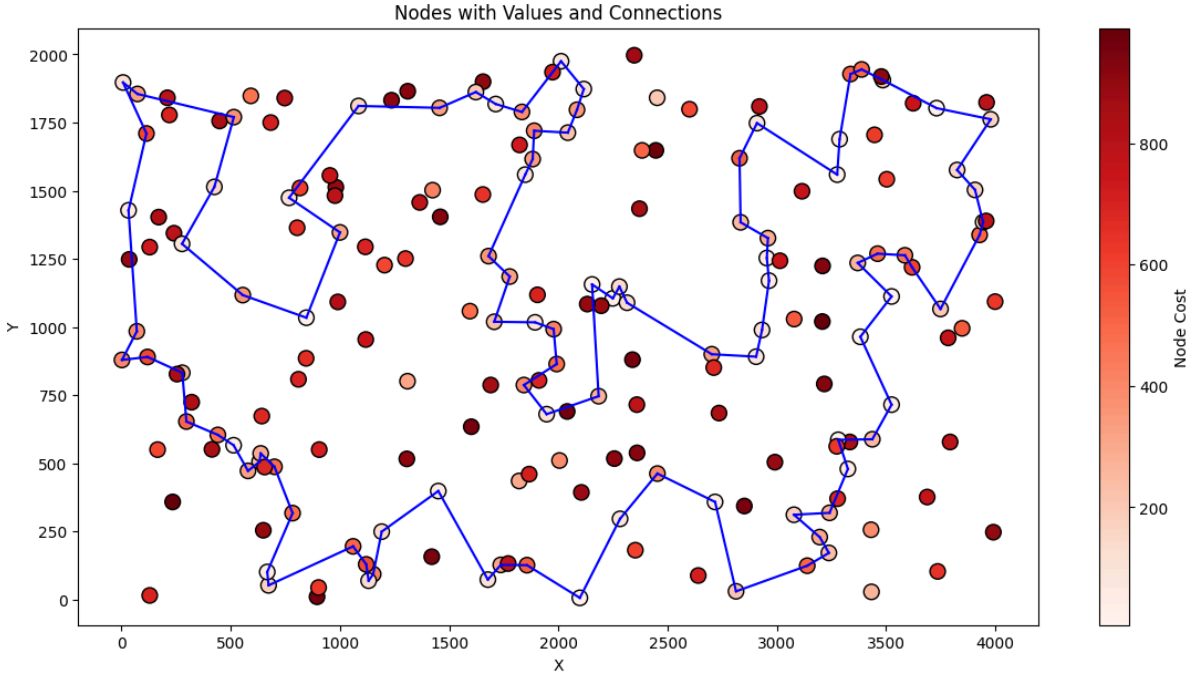

Fig 6. Visualization of the best solution found by the **ILS Random Shuffle (20%) with clustering-based initial solution function** on the TSPB instance.

All best solutions were checked using the solution checker spreadsheet available on eKursy. The lists of node indices in the best solutions and their scores are presented in the table below.

Problem instance	Algorithm	Score	Solution
TSPA	**ILS - Partial Shuffle + Cluster Initialization**	**69095**	**18, 108, 140, 93, 117, 0, 143, 183, 89, 186, 23, 137, 176, 80, 79, 63, 94, 124, 148, 9, 62, 102, 144, 14, 49, 178, 106, 52, 55, 57, 129, 92, 179, 185, 40, 119, 165, 90, 81, 196, 145, 78, 31, 56, 113, 175, 171, 16, 25, 44, 120, 2, 152, 97, 1, 101, 75, 86, 26, 100, 53, 180, 154, 135, 70, 127, 123, 162, 133, 151, 51, 118, 59, 65, 116, 43, 42, 184, 35, 84, 112, 4, 190, 10, 177, 54, 48, 160, 34, 181, 146, 22, 159, 193, 41, 139, 115, 46, 68, 69**
	Evolutionary (Common + Random Recombination + LS)	69554	119, 165, 27, 90, 81, 196, 145, 78, 31, 56, 113, 175, 171, 16, 25, 44, 120, 2, 152, 97, 1, 101, 75, 86, 26, 100, 53, 180, 154, 135, 70, 127, 123, 162, 133, 151, 51, 118, 59, 149, 131, 47, 65, 116, 43, 42, 184, 84, 112, 4, 190, 10, 177, 54, 48, 160, 34, 181, 146, 22, 18, 108, 159, 193, 41, 139, 115, 46, 68, 93, 117, 0, 143, 183, 89, 23, 137, 176, 80, 79, 63, 94, 124, 148, 9, 62, 102, 49, 144, 14, 178, 106, 52, 55, 57, 129, 92, 179, 185, 40
	Evolutionary (Common + Random Recombination)	72242	159, 193, 41, 139, 115, 59, 149, 131, 65, 116, 43, 42, 181, 34, 30, 54, 48, 160, 184, 177, 10, 190, 84, 4, 112, 127, 123, 162, 151, 51, 176, 80, 133, 79, 63, 136, 180, 135, 70, 154, 158, 53, 121, 100, 26, 86, 75, 101, 1, 97, 152, 2, 120, 44, 16, 171, 175, 113, 31, 78, 145, 92, 129, 57, 196, 81, 90, 27, 165, 40, 185, 55, 52, 106, 178, 3, 14, 144, 49, 102, 62, 9, 148, 167, 124, 94, 137, 89, 183, 143, 117, 0, 46, 68, 140, 108, 18, 22, 146, 195
	Evolutionary (Common + Heuristic Recombination + LS)	71881	1, 152, 94, 121, 53, 158, 180, 154, 135, 70, 127, 123, 162, 151, 133, 79, 63, 80, 176, 51, 59, 65, 149, 131, 184, 177, 54, 160, 42, 43, 116, 115, 41, 193, 159, 181, 34, 146, 22, 18, 69, 108, 140, 68, 139, 46, 0, 117, 143, 183, 89, 23, 137, 148, 9, 62, 102, 144, 14, 49, 3, 178, 106, 52, 55, 57, 129, 92, 145, 179, 185, 40, 119, 165, 39, 95, 7, 164, 27, 90, 81, 196, 157, 56, 113, 175, 171, 16, 31, 78, 25, 44, 120, 2, 75, 101, 86, 100, 26, 97
	Evolutionary (Common + Heuristic Recombination)	72050	31, 113, 175, 171, 16, 25, 44, 120, 82, 92, 57, 129, 2, 152, 97, 1, 101, 75, 86, 100, 26, 124, 94, 80, 176, 51, 151, 133, 79, 63, 121, 53, 158, 180, 154, 135, 70, 127, 123, 112, 4, 190, 10, 177, 54, 160, 184, 131, 149, 162, 118, 59, 65, 47, 116, 43, 42, 181, 34, 146, 22, 193, 41, 139, 115, 46, 68, 69, 18, 108, 140, 93, 117, 143, 183, 89, 23, 137, 148, 9, 62, 144, 14, 49, 3, 178, 106, 52, 55, 185, 40, 119, 165, 39, 27, 90, 81, 196, 145, 78
	Evolutionary (ERX Recombination + LS)	69761	34, 181, 42, 43, 116, 65, 47, 131, 149, 162, 151, 51, 118, 59, 115, 46, 68, 139, 41, 193, 159, 22, 18, 108, 140, 93, 117, 0, 143, 183, 89, 186, 23, 137, 176, 80, 133, 79, 63, 94, 148, 9, 62, 144, 14, 102, 49, 3, 178, 106, 52, 55, 185, 40, 119, 165, 90, 81, 196, 31, 56, 113, 175, 171, 16, 25, 44, 120, 78, 145, 179, 57, 92, 129, 2, 152, 97, 1, 101, 75, 86, 26, 53, 180, 154, 135, 70,

			127, 123, 112, 4, 84, 184, 190, 10, 177, 30, 54, 48, 160
	Evolutionary (ERX Recombination)	73113	34, 103, 146, 22, 159, 193, 41, 5, 115, 139, 69, 18, 108, 68, 46, 0, 143, 183, 89, 186, 23, 137, 148, 9, 62, 144, 14, 102, 49, 3, 178, 106, 52, 185, 40, 119, 165, 39, 95, 7, 164, 58, 27, 90, 81, 196, 31, 56, 113, 175, 171, 16, 78, 145, 179, 55, 57, 92, 129, 25, 44, 120, 2, 152, 124, 94, 97, 1, 101, 75, 86, 53, 180, 154, 135, 151, 133, 79, 63, 80, 176, 51, 118, 59, 116, 65, 131, 149, 123, 112, 4, 84, 190, 10, 177, 184, 43, 42, 181, 160
	Large Neighborhood Search (optional LS)	69207	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, 92, 129, 57, 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, 35, 18
	Large Neighborhood Search (no LS)	69250	186, 23, 137, 176, 80, 79, 63, 94, 124, 148, 9, 62, 102, 144, 14, 49, 178, 106, 52, 55, 185, 40, 165, 90, 81, 196, 179, 57, 129, 92, 145, 78, 31, 56, 113, 175, 171, 16, 25, 44, 120, 2, 152, 97, 1, 101, 75, 86, 26, 100, 121, 53, 180, 154, 135, 70, 127, 123, 162, 133, 151, 51, 118, 59, 65, 116, 43, 184, 84, 112, 4, 190, 10, 177, 54, 48, 160, 34, 181, 42, 5, 115, 46, 68, 139, 41, 193, 159, 146, 22, 18, 69, 108, 140, 93, 117, 0, 143, 183, 89
	MSLS	70919	151, 162, 123, 127, 112, 4, 84, 184, 177, 54, 48, 160, 34, 181, 42, 43, 116, 65, 131, 149, 59, 46, 68, 139, 115, 41, 193, 159, 22, 18, 69, 108, 140, 93, 117, 0, 143, 183, 89, 23, 137, 148, 9, 62, 102, 49, 144, 14, 138, 3, 178, 106, 52, 55, 57, 185, 40, 119, 165, 39, 27, 90, 81, 196, 31, 113, 175, 171, 16, 25, 44, 120, 78, 145, 179, 92, 129, 2, 152, 97, 1, 101, 75, 86, 26, 100, 121, 53, 158, 180, 154, 70, 135, 133, 79, 63, 94, 80, 176, 51
	ILS - Partial Shuffle	69141	184, 84, 112, 4, 190, 10, 177, 54, 48, 160, 34, 146, 22, 18, 69, 108, 140, 93, 117, 0, 143, 183, 89, 186, 23, 137, 176, 80, 79, 63, 94, 124, 148, 9, 62, 102, 144, 14, 49, 178, 106, 52, 55, 57, 129, 92, 179, 185, 40, 165, 90, 81, 196, 145, 78, 31, 56, 113, 175, 171, 16, 25, 44, 120, 2, 152, 97, 1, 101, 75, 86, 26, 100, 53, 180, 154, 135, 70, 127, 123, 162, 133, 151, 51, 118, 59, 115, 46, 68, 139, 41, 193, 159, 181, 42, 43, 116, 65, 149, 131
	ILS - MST Perturbation	69246	9, 62, 102, 144, 14, 49, 178, 106, 52, 55, 185, 40, 165, 90, 81, 196, 145, 78, 31, 56, 113, 175, 171, 16, 25, 44, 120, 92, 57, 129, 2, 152, 97, 1, 101, 75, 86, 26, 100, 53, 180, 154, 135, 70, 127, 123, 162, 133, 151, 51, 118, 59, 115, 46, 68, 139, 41, 193, 159, 181, 42, 43, 116, 65, 149, 131, 35, 184, 84, 112, 4, 190, 10, 177, 54, 48, 160, 34, 146, 22, 18, 69, 108, 140, 93, 117, 0, 143, 183, 89, 186, 23, 137, 176, 80, 79, 63, 94, 124, 148
	ILS - Coordinate Change	69460	100, 53, 180, 154, 135, 70, 127, 123, 162, 133, 151, 51, 118, 59, 149, 131, 65, 116, 43, 42, 5, 115, 46, 68, 139, 41, 193, 159, 181, 160, 184, 84, 112, 4, 190, 10, 177, 54, 48, 34, 146, 22, 18, 108, 140, 93, 117, 0, 143, 183, 89, 186, 23, 137, 176, 80, 79, 63, 94, 124, 148, 9, 62, 144, 14, 49, 3, 178, 106, 52, 55, 185, 40, 165, 90, 81, 196, 31, 56, 113, 175, 171, 16, 78, 145, 179, 57, 92, 129, 25, 44, 120, 2, 152, 97, 1, 101, 75, 86, 26
TSPB	**ILS -**	**43519**	**135, 122, 133, 107, 40, 100, 63, 38, 27, 16, 1, 156, 198, 117,**

	Partial Shuffle + Cluster Initialization		**193, 31, 54, 73, 136, 190, 80, 45, 142, 175, 78, 5, 177, 36, 61, 91, 141, 77, 81, 153, 187, 165, 127, 89, 163, 103, 113, 176, 194, 166, 86, 185, 95, 130, 99, 22, 179, 66, 94, 47, 148, 60, 20, 28, 149, 4, 140, 183, 152, 170, 34, 55, 18, 62, 124, 106, 143, 35, 109, 0, 29, 111, 8, 104, 144, 160, 33, 138, 11, 139, 168, 195, 13, 145, 15, 3, 70, 132, 169, 188, 6, 147, 90, 51, 121, 131**
	Evolutionary (Common + Random Recombination + LS)	43811	54, 73, 190, 80, 45, 142, 175, 78, 5, 177, 36, 61, 91, 141, 77, 81, 153, 187, 165, 127, 89, 163, 103, 113, 180, 176, 194, 166, 86, 95, 130, 99, 185, 179, 66, 94, 47, 148, 60, 20, 28, 149, 140, 183, 152, 170, 34, 55, 18, 62, 124, 106, 143, 35, 109, 0, 29, 111, 82, 21, 8, 104, 56, 144, 160, 33, 138, 182, 11, 139, 168, 195, 13, 145, 15, 3, 70, 132, 169, 188, 6, 147, 90, 51, 121, 131, 135, 122, 107, 40, 63, 38, 27, 16, 1, 156, 198, 117, 193, 31
	Evolutionary (Common + Random Recombination)	46931	138, 33, 160, 144, 56, 104, 8, 111, 29, 0, 35, 109, 155, 152, 170, 34, 55, 18, 62, 143, 106, 124, 128, 95, 183, 140, 28, 20, 148, 47, 94, 66, 179, 99, 185, 86, 166, 194, 176, 113, 26, 103, 114, 127, 89, 163, 187, 153, 81, 77, 141, 61, 36, 175, 78, 5, 177, 25, 112, 19, 54, 31, 73, 136, 80, 190, 193, 117, 198, 156, 1, 16, 27, 38, 135, 63, 40, 107, 122, 90, 125, 131, 121, 51, 118, 74, 134, 147, 6, 188, 169, 132, 70, 3, 15, 145, 13, 195, 168, 11
	Evolutionary (Common + Heuristic Recombination + LS)	46611	0, 109, 35, 111, 8, 144, 160, 33, 138, 104, 21, 82, 77, 81, 153, 163, 89, 127, 103, 113, 180, 176, 106, 124, 62, 18, 55, 183, 140, 149, 28, 20, 60, 148, 47, 94, 66, 179, 185, 95, 86, 166, 194, 114, 137, 165, 187, 146, 97, 141, 61, 36, 177, 5, 78, 175, 45, 162, 80, 190, 136, 73, 164, 54, 31, 193, 117, 198, 156, 24, 1, 16, 27, 38, 131, 121, 51, 90, 122, 135, 102, 63, 40, 107, 133, 10, 147, 6, 188, 169, 132, 70, 3, 15, 145, 13, 126, 195, 168, 29
	Evolutionary (Common + Heuristic Recombination)	47111	145, 15, 70, 3, 189, 155, 184, 152, 183, 140, 4, 149, 28, 59, 20, 60, 148, 47, 94, 179, 185, 130, 95, 55, 34, 18, 62, 124, 106, 86, 166, 194, 176, 180, 113, 103, 127, 165, 89, 163, 153, 81, 77, 141, 36, 61, 21, 82, 111, 159, 143, 35, 109, 0, 29, 160, 144, 56, 8, 104, 33, 11, 139, 138, 182, 25, 177, 5, 78, 175, 80, 190, 73, 54, 31, 193, 117, 198, 1, 63, 135, 131, 19, 112, 121, 125, 51, 120, 191, 90, 122, 133, 147, 6, 188, 169, 132, 13, 195, 168
	Evolutionary (ERX Recombination + LS)	44287	8, 33, 160, 29, 0, 109, 35, 143, 106, 124, 62, 18, 55, 34, 152, 183, 140, 4, 149, 28, 20, 60, 148, 47, 94, 66, 179, 185, 22, 99, 130, 95, 86, 166, 194, 176, 180, 113, 103, 127, 89, 163, 187, 153, 81, 77, 141, 61, 36, 177, 5, 45, 142, 78, 175, 80, 190, 136, 73, 164, 31, 54, 193, 117, 198, 156, 1, 16, 27, 38, 63, 100, 40, 107, 10, 133, 122, 135, 131, 121, 51, 90, 191, 147, 134, 6, 188, 169, 132, 70, 3, 15, 145, 13, 195, 168, 139, 11, 138, 104
	Evolutionary (ERX Recombination)	46856	153, 187, 165, 127, 89, 163, 103, 114, 113, 180, 176, 194, 166, 86, 95, 185, 179, 94, 47, 148, 20, 140, 183, 152, 34, 55, 18, 62, 124, 106, 143, 111, 8, 82, 87, 21, 104, 56, 144, 0, 35, 109, 29, 168, 195, 145, 15, 3, 70, 132, 169, 188, 6, 147, 71, 191, 90, 51, 134, 139, 11, 160, 33, 138, 182, 25, 158, 19, 112, 121, 131, 135, 122, 133, 107, 40, 63, 1, 156, 198, 117, 193, 31, 54, 73, 136, 190, 80, 45, 142, 175, 78, 5, 177, 36, 61, 91, 141, 77, 81
	Large Neighborhood Search (optional	43873	33, 160, 144, 104, 8, 21, 82, 111, 29, 0, 109, 35, 143, 106, 124, 62, 18, 55, 34, 170, 152, 183, 140, 4, 149, 28, 20, 60, 148, 47, 94, 66, 172, 179, 22, 99, 130, 95, 185, 86, 166, 194, 176, 113, 103, 127, 89, 163, 187, 153, 81, 77, 141, 91, 61, 36, 177, 5, 45,

	LS)		142, 78, 175, 162, 80, 190, 136, 73, 54, 31, 193, 117, 198, 156, 1, 16, 27, 38, 63, 135, 122, 131, 121, 51, 90, 147, 6, 188, 169, 132, 13, 70, 3, 15, 145, 195, 168, 43, 139, 11, 138
	Large Neighborhood Search (no LS)	44174	193, 54, 31, 73, 136, 190, 80, 162, 175, 78, 5, 177, 25, 182, 138, 139, 11, 33, 160, 144, 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, 28, 149, 4, 140, 183, 152, 170, 34, 55, 18, 62, 124, 106, 143, 35, 109, 0, 29, 168, 195, 145, 15, 3, 70, 13, 132, 169, 188, 6, 147, 51, 121, 131, 90, 133, 107, 40, 63, 122, 135, 38, 27, 16, 1, 156, 198, 117
	MSLS	45365	10, 147, 6, 188, 169, 132, 13, 195, 168, 145, 15, 70, 3, 155, 184, 152, 170, 34, 55, 18, 62, 124, 106, 86, 95, 130, 183, 140, 199, 4, 149, 28, 20, 60, 148, 47, 94, 179, 22, 99, 185, 166, 194, 88, 176, 180, 113, 26, 103, 89, 114, 137, 127, 165, 163, 153, 81, 77, 141, 36, 61, 21, 82, 8, 111, 35, 109, 0, 29, 160, 33, 11, 139, 138, 182, 25, 177, 5, 142, 78, 175, 80, 190, 73, 54, 31, 193, 117, 198, 1, 38, 63, 135, 131, 121, 51, 191, 90, 122, 133
	ILS - Partial Shuffle	43448	81, 153, 187, 163, 103, 89, 127, 137, 114, 113, 176, 194, 166, 86, 185, 95, 130, 99, 22, 179, 66, 94, 47, 148, 60, 20, 28, 149, 4, 140, 183, 152, 170, 34, 55, 18, 62, 124, 106, 143, 35, 109, 0, 29, 111, 8, 104, 144, 160, 33, 138, 11, 139, 168, 195, 13, 145, 15, 3, 70, 132, 169, 188, 6, 147, 90, 51, 121, 131, 135, 122, 133, 107, 40, 63, 38, 27, 16, 1, 156, 198, 117, 193, 31, 54, 73, 136, 190, 80, 45, 142, 175, 78, 5, 177, 36, 61, 91, 141, 77
	ILS - MST Perturbation	43658	89, 127, 137, 114, 103, 113, 176, 194, 166, 86, 95, 130, 185, 179, 66, 94, 47, 148, 60, 20, 28, 149, 4, 140, 183, 152, 170, 34, 55, 18, 62, 128, 124, 106, 143, 35, 109, 0, 29, 111, 82, 8, 104, 144, 160, 33, 138, 182, 11, 139, 168, 195, 13, 145, 15, 3, 70, 132, 169, 188, 6, 147, 191, 90, 51, 121, 131, 135, 122, 107, 40, 63, 38, 27, 1, 156, 198, 117, 193, 31, 54, 73, 136, 190, 80, 45, 142, 175, 78, 5, 177, 36, 61, 91, 141, 77, 81, 153, 187, 163
	ILS - Coordinate Change	43574	81, 153, 187, 163, 103, 89, 127, 137, 114, 113, 176, 194, 166, 86, 185, 95, 130, 99, 22, 179, 66, 94, 47, 148, 60, 20, 28, 149, 4, 140, 183, 152, 170, 34, 55, 18, 62, 124, 106, 143, 35, 109, 0, 29, 111, 8, 104, 144, 160, 33, 138, 11, 139, 168, 195, 13, 145, 15, 3, 70, 132, 169, 188, 6, 147, 90, 51, 121, 131, 135, 122, 133, 107, 40, 63, 38, 27, 16, 1, 156, 198, 117, 193, 31, 54, 73, 136, 190, 80, 45, 142, 175, 78, 5, 177, 36, 61, 91, 141, 77

Table 2. Best solutions and their scores found by each algorithm in both instances.

Method	TSPA av (min - max) [s]	TSPB av (min - max) [s]
Greedy LS Rand	1.273 (1.047 - 1.975)	1.258 (0.991 - 1.646)
Steepest LS Rand	4.283 (3.261 - 6.218)	4.501 (3.292 - 5.609)
Greedy LS Edges Rand	1.171 (0.981 - 1.34)	1.113 (0.945 - 1.446)

Steepest LS Edges Rand	3.571 (2.978 - 4.168)	3.654 (2.976 - 4.364)
Greedy LS Best	0.067 (0.025 - 0.145)	0.077 (0.033 - 0.187)
Steepest LS Best	0.170 (0.055 - 0.529)	0.196 (0.09 - 0.746)
Greedy LS Edges Best	0.062 (0.025 - 0.115)	0.078 (0.036 - 0.212)
Steepest LS Edges Best	0.194 (0.078 - 0.379)	0.229 (0.114 - 0.836)
Steepest Candidate Search	0.584 (0.479 - 0.705)	0.562 (0.481 - 0.693)
MSLS	97.988 (92.859 - 104.159)	90.370 (83.360 - 98.981)
ILS	97.988	90.370
Large Neighborhood Search	97.988	90.370
Evolutionary	97.988	90.370
ILS + cluster-based initialization	**97.988**	**90.370**

Table 3. Minimum, average, and maximum run time achieved by local search methods on both problem instances

4. Conclusions

In conclusion, despite the already achieved scores seeming to be very good, we managed to slightly improve the overall performance on both instances by utilizing a different initial solution strategy with the best-performing ILS algorithm with random shuffling perturbation of 20% consecutive nodes. The created clustering-based initial solution generation function is able to more reliably direct the search to very good solutions by providing the 10 least weight nodes from each of 10 clusters created by using the K-Means algorithm on node coordinates. This approach selects good candidates from a vast area of the search space which might be the main cause for improved performance. In the end the algorithm manages to generate the best minimum, average and second best maximum scores for the TSPA instance and the best average, second best minimum and very good maximum for the TSPB instance.