

ai-cup

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Chapter 1

USI 16th Edition AI Cup

This repo represents my submission for the 2021 AI Cup. More information about how I solved the Cup can be found in the [docs](#) directory.

1.1 How to run

In order to start the TSP-solver, you need to run the following command inside of the root directory of the project:

```
make run
```

1.2 Solvers used

In order to solve the TSPs, I used the following solvers:

- Best Nearest Neighbor (BNN)
- 2.5-opt

1.3 Results

Problem	Best Known	Student Result	Error
ch130	6110	6486	6.15%
d198	15780	16242	2.93%
eil76	538	563	4.65%
fl1577	22249	22939	3.10%
kroa100	21282	21355	0.34%
lin318	42029	43355	3.15%
pcb442	50778	52092	2.59%
pr439	107217	114668	6.95%
rat783	8806	9257	5.12%
u1060	224094	239671	6.95%

Chapter 2

Class Index

2.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Problem	7
Solver	11

Chapter 3

File Index

3.1 File List

Here is a list of all files with brief descriptions:

src/main.cpp	19
src/classes/Problem.hpp	15
src/classes/Solver.hpp	17
src/solvers/nearest_neighbors.hpp	19
src/solvers/two_dot_five_opt.hpp	21
src/solvers/two_opt.hpp	24
src/utls/check_in.hpp	26
src/utls/distance.hpp	27
src/utls/length.hpp	28
src/utls/matrices.hpp	29
src/utls/split.hpp	30

Chapter 4

Class Documentation

4.1 Problem Class Reference

```
#include <Problem.hpp>
```

Public Member Functions

- [Problem](#) (string [filename](#))
Constructor of the [Problem](#) class.
- void [print_info](#) ()
Prints the problem info.

Public Attributes

- bool [exists_optimal](#) = false
- string [name](#)
- string [filename](#)
- int [n_points](#)
- float [best_solution_len](#)
- vector< string > [lines](#)
- vector< int > [optimal_tour](#)
- vector< vector< float > > [points](#)
- vector< vector< float > > [distance_matrix](#)

Private Member Functions

- vector< string > [read_file](#) (string [filename](#))
Reads the problem from a file.
- vector< vector< float > > [parse_points](#) (vector< string > [lines](#), int [n_points](#))
Parses the points of the problem.
- vector< vector< float > > [compute_distance_matrix](#) (vector< vector< float > > [points](#), int [n_points](#))
Compute the distance matrix.
- vector< int > [check_optimal_tour](#) ()
Parses the optimal tour.

4.1.1 Constructor & Destructor Documentation

4.1.1.1 Problem()

```
Problem::Problem (
    string filename ) [inline]
```

Constructor of the [Problem](#) class.

Parameters

<i>filename</i>	The name of the file
-----------------	----------------------

4.1.2 Member Function Documentation

4.1.2.1 check_optimal_tour()

```
vector< int > Problem::check_optimal_tour ( ) [inline], [private]
```

Parses the optimal tour.

Returns

A vector containing the optimal tour

4.1.2.2 compute_distance_matrix()

```
vector< vector< float > > Problem::compute_distance_matrix (
    vector< vector< float > > points,
    int n_points ) [inline], [private]
```

Compute the distance matrix.

Parameters

<i>points</i>	The points of the problem
<i>n_points</i>	The total number of points

Returns

A matrix containing the distance matrix

4.1.2.3 parse_points()

```
vector< vector< float > > Problem::parse_points (
    vector< string > lines,
    int n_points ) [inline], [private]
```

Parses the points of the problem.

Parameters

<i>lines</i>	The lines of the file
<i>n_points</i>	The total number of points

Returns

A matrix containing the points

4.1.2.4 print_info()

```
void Problem::print_info ( ) [inline]
```

Prints the problem info.

4.1.2.5 read_file()

```
vector< string > Problem::read_file (
    string filename ) [inline], [private]
```

Reads the problem from a file.

Parameters

<i>filename</i>	The name of the file
-----------------	----------------------

Returns

A vector of strings containing the lines of the file

4.1.3 Member Data Documentation

4.1.3.1 best_solution_len

`float Problem::best_solution_len`

4.1.3.2 distance_matrix

`vector<vector<float> > Problem::distance_matrix`

4.1.3.3 exists_optimal

`bool Problem::exists_optimal = false`

4.1.3.4 filename

`string Problem::filename`

4.1.3.5 lines

`vector<string> Problem::lines`

4.1.3.6 n_points

`int Problem::n_points`

4.1.3.7 name

`string Problem::name`

4.1.3.8 optimal_tour

```
vector<int> Problem::optimal_tour
```

4.1.3.9 points

```
vector<vector<float> > Problem::points
```

The documentation for this class was generated from the following file:

- src/classes/[Problem.hpp](#)

4.2 Solver Class Reference

```
#include <Solver.hpp>
```

Public Member Functions

- [Solver](#) ([Problem](#) *[problem](#))
Construct a new [Solver](#) object.

Private Member Functions

- vector< float > [compute_solution](#) ()
Solve the problem using the given algorithms.
- bool [check_validity](#) (vector< float > [solution](#))
Check if the solution is valid.
- float [gap](#) ()
Compute gap.

Private Attributes

- int [algo_name](#)
- float [duration](#)
- int [found_length](#)
- [Problem](#) * [problem](#)
- vector< float > [solution](#)

4.2.1 Constructor & Destructor Documentation

4.2.1.1 Solver()

```
Solver::Solver (  
    Problem * problem ) [inline]
```

Construct a new [Solver](#) object.

Parameters

<i>problem</i>	The problem to solve
----------------	----------------------

4.2.2 Member Function Documentation

4.2.2.1 `check_validity()`

```
bool Solver::check_validity (
    vector< float > solution )  [inline], [private]
```

Check if the solution is valid.

Parameters

<i>solution</i>	The solution vector
-----------------	---------------------

Returns

true If the solution is valid
false If the solution is not valid

4.2.2.2 `compute_solution()`

```
vector< float > Solver::compute_solution ( )  [inline], [private]
```

Solve the problem using the given algorithms.

Returns

The solution vector of the problem

4.2.2.3 `gap()`

```
float Solver::gap ( )  [inline], [private]
```

Compute gap.

Compute the gap between the best known solution and the solution from the current algorithm.

Returns

The gap

4.2.3 Member Data Documentation

4.2.3.1 algo_name

```
int Solver::algo_name [private]
```

4.2.3.2 duration

```
float Solver::duration [private]
```

4.2.3.3 found_length

```
int Solver::found_length [private]
```

4.2.3.4 problem

```
Problem* Solver::problem [private]
```

4.2.3.5 solution

```
vector<float> Solver::solution [private]
```

The documentation for this class was generated from the following file:

- [src/classes/Solver.hpp](#)

Chapter 5

File Documentation

5.1 README.md File Reference

5.2 src/classes/Problem.hpp File Reference

```
#include <vector>
#include <string>
#include <fstream>
#include <iostream>
#include "../utils/split.hpp"
#include "../utils/matrices.hpp"
#include "../utils/distance.hpp"
```

Classes

- class [Problem](#)

Macros

- #define [PROBLEM_HPP](#)

5.2.1 Macro Definition Documentation

5.2.1.1 PROBLEM_HPP

```
#define PROBLEM_HPP
```

5.3 Problem.hpp

[Go to the documentation of this file.](#)

```

1 #include <vector>
2 #include <string>
3 #include <fstream>
4 #include <iostream>
5
6 #include "../utils/split.hpp"
7 #include "../utils/matrices.hpp"
8 #include "../utils/distance.hpp"
9
10 using namespace std;
11
12 #ifndef PROBLEM_HPP
13 #define PROBLEM_HPP
14
15 class Problem {
16 public:
17     bool exists_optimal = false;
18
19     string name;
20     string filename;
21
22     int n_points;
23     float best_solution_len;
24
25     vector<string> lines;
26     vector<int> optimal_tour;
27     vector<vector<float>> > points;
28     vector<vector<float>> > distance_matrix;
29
30
31     Problem(string filename) {
32         this->filename = filename;
33         this->lines = read_file(filename);
34
35         this->name = split(lines[0], " : ")[1];
36         this->n_points = stoi(split(lines[3], " : ")[1]);
37         this->best_solution_len = stof(split(lines[5], " : ")[1]);
38
39         this->points = parse_points(lines, this->n_points);
40         this->distance_matrix = compute_distance_matrix(this->points, this->n_points);
41         this->optimal_tour = check_optimal_tour();
42     }
43
44     void print_info() {
45         cout << "\n\n#####" << endl;
46         cout << "Problem: " << this->name << endl;
47         cout << "Number of points: " << this->n_points << endl;
48         cout << "Best solution: " << (int)this->best_solution_len << endl;
49         cout << "Optimal tour: " << boolalpha << this->exists_optimal << endl;
50     }
51
52 private:
53     vector<string> read_file(string filename) {
54         ifstream file(filename);
55         vector<string> lines;
56         string line;
57
58         while (getline(file, line)) {
59             lines.push_back(line);
60         }
61
62         return lines;
63     }
64
65     vector<vector<float>> > parse_points(vector<string> lines, int n_points) {
66         vector<vector<float>> > points(n_points, vector<float>(3));
67
68         for (int i = 7; i < n_points + 7; i++) {
69             points[i-7][0] = stof(split(lines[i], " ")[0]);
70             points[i-7][1] = stof(split(lines[i], " ")[1]);
71             points[i-7][2] = stof(split(lines[i], " ")[2]);
72         }
73
74         return points;
75     }
76
77     vector<vector<float>> > compute_distance_matrix(vector<vector<float>> > points, int n_points) {
78         vector<vector<float>> > distance_matrix(n_points, vector<float>(n_points));
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110

```

```

111     for (int i = 0; i < n_points; i++) {
112         for (int j = i; j < n_points; j++) {
113             distance_matrix[i][j] = distance(points[i], points[j]);
114         }
115     }
116
117     vector<vector<float>> > transposed_matrix = m_transpose(distance_matrix);
118     distance_matrix = m_sum(distance_matrix, transposed_matrix);
119
120     return distance_matrix;
121 }
122
123
129 vector<int> check_optimal_tour() {
130     vector<int> tour(this->n_points);
131
132     if (this->filename == "../problems/eil76.tsp" || this->filename == "../problems/kroA100.tsp") {
133         this->exists_optimal = true;
134
135         ifstream file(this->filename.replace(this->filename.end()-3, this->filename.end(), "opt.tour"));
136         vector<string> lines;
137         string line;
138
139         while (getline(file, line)) {
140             lines.push_back(line);
141         }
142
143         for (int i = 6; i < this->n_points + 6; i++) {
144             tour[i-6] = stoi(lines[i]);
145         }
146
147         return tour;
148     }
149
150     return vector<int>();
151 }
152 };
153
154 #endif // PROBLEM_HPP

```

5.4 src/classes/Solver.hpp File Reference

```

#include <ctime>
#include <vector>
#include "../utils/length.hpp"
#include "../utils/check_in.hpp"
#include "../solvers/two_opt.hpp"
#include "../solvers/two_dot_five_opt.hpp"
#include "../solvers/nearest_neighbors.hpp"

```

Classes

- class [Solver](#)

Macros

- #define [SOLVER_HPP](#)

5.4.1 Macro Definition Documentation

5.4.1.1 SOLVER_HPP

```
#define SOLVER_HPP
```

5.5 Solver.hpp

[Go to the documentation of this file.](#)

```
1 #include <ctime>
2 #include <vector>
3
4 #include "../utils/length.hpp"
5 #include "../utils/check_in.hpp"
6
7 #include "../solvers/two_opt.hpp"
8 #include "../solvers/two_dot_five_opt.hpp"
9 #include "../solvers/nearest_neighbors.hpp"
10
11
12 using namespace std;
13
14 #ifndef SOLVER_HPP
15 #define SOLVER_HPP
16
17 class Solver {
18 private:
19     int algo_name;
20     float duration;
21     int found_length;
22
23     Problem * problem;
24     vector<float> solution;
25
26
32     vector<float> compute_solution() {
33         clock_t start = clock();
34
35         cout << endl;
36         cout << "### Solving problem with ['best_nearest_neighbors', 'two_dot_five_opt'] ###" << endl;
37
38         vector<float> solution = best_nearest_neighbors(this->problem);
39         solution = two_dot_five_opt(solution, this->problem);
40
41         if (!check_validity(solution)) {
42             cout << "ERROR: Solution is not valid" << endl;
43             exit(1);
44         }
45
46         this->duration = (clock() - start) / (double) CLOCKS_PER_SEC;
47         this->found_length = length(solution, this->problem->distance_matrix);
48
49         cout << "Solution found in " << this->duration << " seconds" << endl;
50         cout << "Legnth of solution: " << this->found_length << endl;
51         cout << "Gap between solutions: " << fixed << setprecision(2) << this->gap() << "%" << endl;
52
53         return solution;
54     }
55
56
64     bool check_validity(vector<float> solution) {
65         int sum = 0;
66
67         for (int i = 0; i < this->problem->n_points; i++) {
68             if (check_in(solution, i)) sum += 1;
69         }
70
71         return sum == this->problem->n_points;
72     }
73
74
83     float gap() {
84         float num = this->found_length - this->problem->best_solution_len;
85         float den = this->problem->best_solution_len;
86
87         return (num / den) * 100.0;
88     }
89
90
91 public:
97     Solver(Problem * problem) {
```



```
98     this->duration = 0;
99     this->found_length = 0;
100
101     this->problem = problem;
102     this->solution = compute_solution();
103 }
104 };
105
106 #endif // SOLVER_HPP
```

5.6 src/main.cpp File Reference

```
#include <vector>
#include "../classes/Problem.hpp"
#include "../classes/Solver.hpp"
```

Functions

- int [main](#) (int argc, char **argv)

5.6.1 Function Documentation

5.6.1.1 main()

```
int main (
    int argc,
    char ** argv )
```

5.7 src/solvers/nearest_neighbors.hpp File Reference

```
#include <vector>
```

Functions

- vector< float > [nearest_neighbors](#) ([Problem](#) *problem, vector< bool > &visited, int start=0)
Nearest neighbors.
- vector< float > [best_nearest_neighbors](#) ([Problem](#) *problem)
Best nearest neighbors.

5.7.1 Function Documentation

5.7.1.1 best_nearest_neighbors()

```
vector< float > best_nearest_neighbors (
    Problem * problem )
```

Best nearest neighbors.

The best nearest neighbors algorithm.

Parameters

<i>problem</i>	The problem to solve
----------------	----------------------

Returns

The solution

5.7.1.2 nearest_neighbors()

```
vector< float > nearest_neighbors (
    Problem * problem,
    vector< bool > & visited,
    int start = 0 )
```

Nearest neighbors.

The nearest neighbors algorithm.

Parameters

<i>problem</i>	The problem to solve
<i>visited</i>	The visited nodes
<i>start</i>	The starting node

Returns

The solution

5.8 nearest_neighbors.hpp

[Go to the documentation of this file.](#)

```
1 #include <vector>
2
3 using namespace std;
4
5
16 vector<float> nearest_neighbors(Problem * problem, vector<bool> & visited, int start=0) {
17     vector<float> result;
18
19     result.push_back(start);
20     visited[start] = true;
21
22     for (int i = 0; i < problem->n_points-1; i++) {
23         float min_dist = INFINITY;
24         float min_dist_idx = 0;
25
26         for (int j = 0; j < problem->n_points; j++) {
27             if (i == j) continue;
28
29             float dist = problem->distance_matrix[result[result.size()-1]][j];
30
31             if (dist < min_dist && !visited[j]) {
32                 min_dist = dist;
33                 min_dist_idx = j;
34             }
35         }
36     }
37 }
```

```

35     }
36
37     visited[min_dist_idx] = true;
38     result.push_back(min_dist_idx);
39 }
40
41 return result;
42 }
43
44
45 vector<float> best_nearest_neighbors(Problem * problem) {
46     vector<float> result;
47
48     float min_length = INFINITY;
49
50     for (int i = 0; i < problem->n_points; i++) {
51         vector<bool> visited(problem->n_points, false);
52
53         vector<float> temp = nearest_neighbors(problem, visited, i);
54         int curr_len = length(temp, problem->distance_matrix);
55
56         if (curr_len < min_length) {
57             result = temp;
58             min_length = curr_len;
59         }
60     }
61
62     return result;
63 }

```

5.9 src/solvers/two_dot_five_opt.hpp File Reference

```

#include <tuple>
#include <vector>
#include <algorithm>

```

Functions

- tuple< vector< float >, int > [two_dot_five_opt_step](#) (vector< float > solution, [Problem](#) *problem)
Two-dot-five-opt algorithm step.
- vector< float > [two_dot_five_opt](#) (vector< float > solution, [Problem](#) *problem)
Two-dot-five-opt algorithm.

5.9.1 Function Documentation

5.9.1.1 two_dot_five_opt()

```

vector< float > two_dot_five_opt (
    vector< float > solution,
    Problem * problem )

```

Two-dot-five-opt algorithm.

Perform the two-dot-five-opt algorithm on a solution.

Parameters

<i>solution</i>	Solution to be optimized
<i>problem</i>	Problem to be solved

Returns

The optimized solution

5.9.1.2 two_dot_five_opt_step()

```
tuple< vector< float >, int > two_dot_five_opt_step (
    vector< float > solution,
    Problem * problem )
```

Two-dot-five-opt algorithm step.

Perform a single step of the two-dot-five-opt algorithm.

Parameters

<i>solution</i>	Solution to be optimized
<i>problem</i>	Problem to be solved

Returns

Tuple containing the new solution and the total gain

5.10 two_dot_five_opt.hpp

[Go to the documentation of this file.](#)

```
1 #include <tuple>
2 #include <vector>
3 #include <algorithm>
4
5 using namespace std;
6
7
17 tuple<vector<float>, int> two_dot_five_opt_step(vector<float> solution, Problem * problem) {
18     int gain = 0;
19
20     int best_i = 1;
21     int best_j = 2;
22
23     int method = -1;
24     bool swapped = false;
25
26     vector<float> new_solution = solution;
27
28     for (int i = 1; i < solution.size()-2; i++) {
29         for (int j = i+1; j < solution.size()-1; j++) {
30             // 2-opt gain
31             int old_two_opt_len = problem->distance_matrix[new_solution[i]][new_solution[i-1]]
32                 + problem->distance_matrix[new_solution[j]][new_solution[j+1]];
33             int new_two_opt_len = problem->distance_matrix[new_solution[j]][new_solution[i-1]]
34                 + problem->distance_matrix[new_solution[i]][new_solution[j+1]];
```

```

35
36     int two_opt_gain = - old_two_opt_len + new_two_opt_len;
37
38     // Node shift 1 gain
39     int old_node_shift_1_len = problem->distance_matrix[new_solution[i]][new_solution[i-1]]
40                               + problem->distance_matrix[new_solution[i]][new_solution[i+1]]
41                               + problem->distance_matrix[new_solution[j]][new_solution[j+1]];
42     int new_node_shift_1_len = problem->distance_matrix[new_solution[i-1]][new_solution[i+1]]
43                               + problem->distance_matrix[new_solution[i]][new_solution[j]]
44                               + problem->distance_matrix[new_solution[i]][new_solution[j+1]];
45
46     int node_shift_1_gain = - old_node_shift_1_len + new_node_shift_1_len;
47
48     // Node shift 2 gain
49     int old_node_shift_2_len = problem->distance_matrix[new_solution[i]][new_solution[i-1]]
50                               + problem->distance_matrix[new_solution[j]][new_solution[j-1]]
51                               + problem->distance_matrix[new_solution[j]][new_solution[j+1]];
52     int new_node_shift_2_len = problem->distance_matrix[new_solution[j]][new_solution[i-1]]
53                               + problem->distance_matrix[new_solution[i]][new_solution[j]]
54                               + problem->distance_matrix[new_solution[j-1]][new_solution[j+1]];
55
56     int node_shift_2_gain = - old_node_shift_2_len + new_node_shift_2_len;
57
58     if (two_opt_gain < gain || node_shift_1_gain < gain || node_shift_2_gain < gain) {
59         best_i = i;
60         best_j = j;
61         swapped = true;
62
63         if (two_opt_gain < node_shift_1_gain && two_opt_gain < node_shift_2_gain) {
64             method = 1;
65             gain = two_opt_gain;
66         } else if (node_shift_1_gain < two_opt_gain && node_shift_1_gain < node_shift_2_gain) {
67             method = 2;
68             gain = node_shift_1_gain;
69         } else if (node_shift_2_gain < two_opt_gain && node_shift_2_gain < node_shift_1_gain) {
70             method = 3;
71             gain = node_shift_2_gain;
72         }
73     }
74 }
75 }
76
77 if (method == 1) {
78     // Two-opt swap
79     reverse(new_solution.begin() + best_i, new_solution.begin() + best_j + 1);
80 } else if (method == 2) {
81     // Node shift 1 swap
82     vector<float> array_one = {new_solution.begin(), new_solution.begin() + best_i};
83     vector<float> array_two = {new_solution.begin() + best_i + 1, new_solution.begin() + best_j + 1};
84     vector<float> array_three = {new_solution.begin() + best_j + 1, new_solution.end()};
85
86     vector<float> sol = array_one;
87     sol.insert(sol.end(), array_two.begin(), array_two.end());
88     sol.push_back(new_solution[best_i]);
89     sol.insert(sol.end(), array_three.begin(), array_three.end());
90
91     new_solution = sol;
92 } else if (method == 3) {
93     // Node shift 2 swap
94     vector<float> array_one = {new_solution.begin(), new_solution.begin() + best_i};
95     vector<float> array_two = {new_solution.begin() + best_i, new_solution.begin() + best_j};
96     vector<float> array_three = {new_solution.begin() + best_j + 1, new_solution.end()};
97
98     vector<float> sol = array_one;
99     sol.push_back(new_solution[best_j]);
100     sol.insert(sol.end(), array_two.begin(), array_two.end());
101     sol.insert(sol.end(), array_three.begin(), array_three.end());
102
103     new_solution = sol;
104 } else {
105     return make_tuple(solution, false);
106 }
107
108 return make_tuple(new_solution, swapped);
109 }
110
111
112 vector<float> two_dot_five_opt(vector<float> solution, Problem * problem) {
113     bool swapping = true;
114     vector<float> new_solution = solution;
115
116     while (swapping) {
117         auto res = two_dot_five_opt_step(new_solution, problem);
118         new_solution = get<0>(res);
119         swapping = get<1>(res);
120     }
121 }
122
123

```

```

131     return new_solution;
132 }

```

5.11 src/solvers/two_opt.hpp File Reference

```

#include <tuple>
#include <vector>
#include <algorithm>

```

Functions

- tuple< vector< float >, int > [two_opt_step](#) (vector< float > solution, [Problem](#) *problem)
Two-opt algorithm step.
- vector< float > [two_opt](#) (vector< float > solution, [Problem](#) *problem)
Two-opt algorithm.

5.11.1 Function Documentation

5.11.1.1 two_opt()

```

vector< float > two_opt (
    vector< float > solution,
    Problem * problem )

```

Two-opt algorithm.

Perform the two-opt algorithm on a solution.

Parameters

<i>solution</i>	Solution to be optimized
<i>problem</i>	Problem to be solved

Returns

The optimized solution

5.11.1.2 two_opt_step()

```

tuple< vector< float >, int > two_opt_step (
    vector< float > solution,
    Problem * problem )

```

Two-opt algorithm step.

Perform a single step of the two-opt algorithm.

Parameters

<i>solution</i>	Solution to be optimized
<i>problem</i>	Problem to be solved

Returns

Tuple containing the new solution and the total gain

5.12 two_opt.hpp

[Go to the documentation of this file.](#)

```

1 #include <tuple>
2 #include <vector>
3 #include <algorithm>
4
5 using namespace std;
6
7
17 tuple<vector<float>, int> two_opt_step(vector<float> solution, Problem * problem) {
18     int gain = 0;
19
20     int best_i = 1;
21     int best_j = 2;
22
23     bool swapped = false;
24
25     vector<float> new_solution = solution;
26
27     for (int i = 1; i < solution.size()-2; i++) {
28         for (int j = i+1; j < solution.size()-1; j++) {
29             int old_link_len = problem->distance_matrix[new_solution[i]][new_solution[i-1]]
30                 + problem->distance_matrix[new_solution[j]][new_solution[j+1]];
31             int new_link_len = problem->distance_matrix[new_solution[j]][new_solution[i-1]]
32                 + problem->distance_matrix[new_solution[i]][new_solution[j+1]];
33
34             int gain_value = - old_link_len + new_link_len;
35
36             if (gain_value < gain) {
37                 best_i = i;
38                 best_j = j;
39                 swapped = true;
40                 gain = gain_value;
41             }
42         }
43     }
44
45     reverse(new_solution.begin() + best_i, new_solution.begin() + best_j + 1);
46
47     return make_tuple(new_solution, swapped);
48 }
49
50
60 vector<float> two_opt(vector<float> solution, Problem * problem) {
61     bool swapping = true;
62     vector<float> new_solution = solution;
63
64     while (swapping) {
65         auto res = two_opt_step(new_solution, problem);
66         new_solution = get<0>(res);
67         swapping = get<1>(res);
68     }
69
70     return new_solution;
71 }

```

5.13 src/utils/check_in.hpp File Reference

```
#include <vector>
```

Functions

- bool [check_in](#) (vector< float > result, float j)
Check if the given number is in the given vector.

5.13.1 Function Documentation

5.13.1.1 check_in()

```
bool check_in (  
    vector< float > result,  
    float j )
```

Check if the given number is in the given vector.

Parameters

<i>result</i>	The vector to check.
<i>j</i>	The number to check.

Returns

true The number is in the vector.
false The number is not in the vector.

5.14 check_in.hpp

[Go to the documentation of this file.](#)

```
1 #include <vector>  
2  
3 using namespace std;  
4  
5  
14 bool check_in(vector<float> result, float j) {  
15     for (auto i : result) {  
16         if (i == j) return true;  
17     }  
18  
19     return false;  
20 }
```


5.15 src/utils/distance.hpp File Reference

```
#include <cmath>
#include <vector>
```

Functions

- int [distance](#) (vector< float > p1, vector< float > p2)
Compute the Euclidean distance between two points.

5.15.1 Function Documentation

5.15.1.1 distance()

```
int distance (
    vector< float > p1,
    vector< float > p2 )
```

Compute the Euclidean distance between two points.

Parameters

<i>p1</i>	The first point
<i>p2</i>	The second point

Returns

The Euclidean distance

5.16 distance.hpp

[Go to the documentation of this file.](#)

```
1 #include <cmath>
2 #include <vector>
3
4 using namespace std;
5
6
14 int distance(vector<float> p1, vector<float> p2) {
15     int x1 = p1[1];
16     int y1 = p1[2];
17     int x2 = p2[1];
18     int y2 = p2[2];
19
20     return round(sqrt(pow(x1 - x2, 2) + pow(y1 - y2, 2)));
21 }
```

5.17 src/utils/length.hpp File Reference

```
#include <vector>
```

Functions

- int [length](#) (vector< float > solution, vector< vector< float > > distance_matrix)
Length of tour.

5.17.1 Function Documentation

5.17.1.1 length()

```
int length (
    vector< float > solution,
    vector< vector< float > > distance_matrix )
```

Length of tour.

This function computes the length of a given tour.

Parameters

<i>solution</i>	The tour
<i>distance_matrix</i>	The distance matrix

Returns

The length of the tour

5.18 length.hpp

[Go to the documentation of this file.](#)

```
1 #include <vector>
2
3 using namespace std;
4
5
15 int length(vector<float> solution, vector<vector<float> > distance_matrix) {
16     int length = 0;
17     int starting_node = solution[0];
18     int from_node = starting_node;
19
20     for (int i = 1; i < solution.size(); i++) {
21         int to_node = solution[i];
22         length += distance_matrix[from_node][to_node];
23         from_node = to_node;
24     }
25
26     length += distance_matrix[starting_node][from_node];
27
28     return length;
29 }
```

5.19 src/utils/matrices.hpp File Reference

```
#include <vector>
```

Functions

- `vector< vector< float > > m_transpose (vector< vector< float > > b)`
Computes the transpose of a matrix.
- `vector< vector< float > > m_sum (vector< vector< float > > a, vector< vector< float > > b)`
Compute the sum of two matrices.

5.19.1 Function Documentation

5.19.1.1 m_sum()

```
vector< vector< float > > m_sum (
    vector< vector< float > > a,
    vector< vector< float > > b )
```

Compute the sum of two matrices.

Parameters

<i>a</i>	The first matrix
<i>b</i>	The second matrix

Returns

The resulting matrix

5.19.1.2 m_transpose()

```
vector< vector< float > > m_transpose (
    vector< vector< float > > b )
```

Computes the transpose of a matrix.

Parameters

<i>b</i>	The matrix to transpose
----------	-------------------------

Returns

The transposed matrix

5.20 matrices.hpp

[Go to the documentation of this file.](#)

```

1  #include <vector>
2
3  using namespace std;
4
5
12 vector<vector<float> > m_transpose(vector<vector<float> > b) {
13     vector<vector<float> > trans_vec(b[0].size(), vector<float>(b[0].size()));
14
15     for (int i = 0; i < b.size(); i++) {
16         for (int j = 0; j < b[i].size(); j++) {
17             if (trans_vec[j].size() != b.size()) {
18                 trans_vec[j].resize(b.size());
19             }
20
21             trans_vec[j][i] = b[i][j];
22         }
23     }
24
25     return trans_vec;
26 }
27
28
36 vector<vector<float> > m_sum(vector<vector<float> > a, vector<vector<float> > b) {
37     vector<vector<float> > result(a[0].size(), vector<float>(a[0].size()));
38
39     for (int i = 0; i < a.size(); i++) {
40         for (int j = 0; j < a[i].size(); j++) {
41             result[i][j] = a[i][j] + b[i][j];
42         }
43     }
44
45     return result;
46 }

```

5.21 src/utils/split.hpp File Reference

```

#include <vector>
#include <string>
#include <sstream>

```

Functions

- vector< string > [split](#) (string s, string delimiter)
Splits a string into a vector of strings given a delimiter.

5.21.1 Function Documentation

5.21.1.1 split()

```

vector< string > split (
    string s,
    string delimiter )

```

Splits a string into a vector of strings given a delimiter.

Parameters

<i>s</i>	The string to split`
<i>delimiter</i>	The delimiter

Returns

vector<string>

5.22 split.hpp

[Go to the documentation of this file.](#)

```
1 #include <vector>
2 #include <string>
3 #include <sstream>
4
5 using namespace std;
6
7
15 vector<string> split(string s, string delimiter) {
16     size_t pos_end;
17     size_t pos_start = 0;
18     size_t delim_len = delimiter.length();
19
20     string token;
21     vector<string> res;
22
23     while ((pos_end = s.find (delimiter, pos_start)) != string::npos) {
24         token = s.substr (pos_start, pos_end - pos_start);
25         pos_start = pos_end + delim_len;
26         res.push_back (token);
27     }
28
29     res.push_back (s.substr (pos_start));
30     return res;
31 }
```


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