

KU LEUVEN

GENETIC ALGORITHMS

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**TSP**

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# 1 Implementation

## 1.1 Representation

The original code employed adjacency representation. In adjacency representation a tour is represented as a list of  $n$  cities where city  $j$  is listed in position  $i$  if and only if the tour leads from city  $i$  to city  $j$ . Thus, the list:

$$(7 \ 6 \ 8 \ 5 \ 3 \ 4 \ 2 \ 1)$$

represents the tour:

$$3-8-1-7-2-6-4-5$$

<sup>1</sup>

In our implementation, we have decided to use path representation. Path representation is the most natural way of representing a tour. This can be easily seen with the following example. The list:

$$(1 \ 2 \ 7 \ 5 \ 6 \ 3 \ 4)$$

represents the path

$$1-2-7-5-6-3-4$$

It was also the simplest representation possible for this problem, and it was easy to implement, as the tour was first encoded in path representation, and then translated to adjacency representation using the function `path2adj`. Finally, it was translated again to path representation to be used in the plots with the function `adj2path`.

## 1.2 Crossover

The new representation required a new crossover operator. The available options were:

- Partially Matched Crossover (PMX)
- Order Crossover (OX)
- Cyclic Crossover (CX)
- Edge Recombination Crossover (ERX)

The one selected is Order Crossover. This crossover exploits a property of the path representation, that the order of the cities (not their positions) are important. It constructs an offspring by choosing a subtour of one parent and preserving the relative order of cities of the other parent. Let's consider the following tours:

$$\begin{aligned} &(1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8) \\ &(2 \ 4 \ 6 \ 8 \ 7 \ 5 \ 3 \ 1) \end{aligned}$$

---

<sup>1</sup>This explanation can be found in the slides about Traveling Salesman Problem

If we choose the cut point between the second and the third city, and the second cut point between the fifth and the sixth, we have:

$$\begin{aligned} & (1 \ 2 — 3 \ 4 \ 5 — 6 \ 7 \ 8) \\ & (2 \ 4 — 6 \ 8 \ 7 — 5 \ 3 \ 1) \end{aligned}$$

And the offspring is created copying the segments between the cut points, and then, starting from the second cut points of one parent, the rest of the cities are copied in the order in which they appear in the other parent, giving:

$$\begin{aligned} & (8 \ 7 — 3 \ 4 \ 5 — 1 \ 2 \ 6) \\ & (4 \ 5 — 6 \ 8 \ 7 — 1 \ 2 \ 3) \end{aligned}$$

### 1.3 Mutation

We were also asked to implement a new mutation operator. For this task, multiple and different options where available, such as Exchange Mutation, Scramble Mutation, Displacement Mutation or Insertion Mutation. As the crossover operator chosen exploits the order property aforementioned, we decided that the mutation should break this order in some way to avoid reaching a local optima due to the lack of diversity in the order.

The mutation operator selected for this problem is insertion mutation due to its simplicity and effectiveness. This mutation works in the following way. Imagine that we have the path:

$$0 \ 1 \ \mathbf{2} \ 3 \ 4 \ 5 \ 6 \ 7$$

Take the 2 out of the sequence,

$$0 \ 1 \ 3 \ 4 \ 5 \ 6 \ 7$$

and reinsert the 2 at a randomly chosen position:

$$0 \ 1 \ 3 \ 4 \ 5 \ \mathbf{2} \ 6 \ 7$$

### 1.4 Fitness Function

The fitness function has been changed as the original one worked with adjacency representation. The simplest way to adapt the old function to the new representation was using `path2adj`, converting the path to adjacency representation, and then computing the fitness in the same way as it was computed before.

## 2 Experiments

In order to properly study and select the different configurations, it is necessary to analyze the behaviour of the algorithm, when we modify one parameter at a time. An automated test was developed for this purpose, provided in the annex, with which we run a set of tests,

changing the number of individuals, the number of generations, the percentage of elitism, and the balance of percentage of mutation and crossover. Each test, in each city is run a total of 5 times, and the average is what is taken into account.

After that, a set of tests, created from the results obtained in the general set, is made, by selecting specific values. Both the general, and the specific tests will serve as a medium to compare both representations, in order to look for differences (or lack thereof)

## 2.1 General tests

For the general tests, the default values are:

- Number of individuals - 50
- Number of generations - 50
- Elitism - 0.05
- Crossover - 0.95
- Mutation - 0.05
- Stop percentage condition - 0.95
- Detection of loops on

And, the different values for each modified parameter are:

- Number of individuals - [50,100,150,200,500,750,1000]
- Number of individuals - [50,100,150,200,500,750,1000]
- Elitism percentage - [0,0.05,0.1,0.2,0.5,0.75,1]
- Crossover—Mutation balance - [1—0,0.95—0.05,0.9—0.1,0.75—0.25,0.5—0.5,0.25—0.75,0—1]

### 2.1.1 Original code

Due to space limitations, we will limit ourselves to only discuss the results of the general tests, while referring to the correspondent graph in the appendix.

When it comes to number of individuals, as expected, a relatively low number of individuals does not provide adequate results, as can be observed by looking at the start of the graph (3.13.1). Almost all datasets start in global maximum, and only a couple in a local max. However, the majority of them have one of their lowest point when the number of individuals is 200 (except for the highest dataset, which has its lowest point at 750) and from that point, it stays constant, or even raises, hence it can be said that any number of individuals higher than 200 would not be beneficial, and actually be just cumbersome when it comes to computational cost.

Regarding the number of generations (3.13.2), once again, it is to be expected that a low quantity of generations will not yield good results. But that is not the only thing the number of individuals and generations have in common, since it seems like 200 is one of the best options for the number of generations. There are some differences, for instance, at lower quantities of generations, there is more fluctuation, and more datasets are positive towards higher number of generations. In the specific tests this will be further studied, whether 200, or a higher number is better, and whether the higher associated computational cost is worth.

When it comes to the percentage of elitism (3.13.3), the results are clearer. With no exceptions, the lowest value for every single one of the datasets is between 0.05 and 0.1, any higher, or any lower, and the distance skyrockets, having the highest distances values at elitism = 1.

This phenomena has an easy explanation, the higher the elitism, the more likely it is that the algorithm will stay at a local maxima.

For crossover and mutation (3.13.4), the test reflects perfectly the balance between exploitation and exploration, the overall result shows that the best performance comes when mutation has a value of 0.5, and crossover 0.5.

Any value of mutation higher than 0.5, and the results start to worsen, because there is too much exploitation, and too little exploration. Any value of mutation lower than 0.5, and the results, most of the cases, are far worse. This leads to the conclusion that 0.5 is the candidate for the specific tests, although the nature of the result makes it necessary to test other values, since, we think these results are a bit odd, hence we will further study in the specific tests, order to make a conclusion.

### 2.1.2 Modified code

As explained in the implementation section, the representation we implemented is path representation. Again, we will only discuss the results, the graphs can be found in the appendix

Similarly to adjacency representation, the result for the test (3.13.5) of increasing the number of individuals has a generally located minimum local at 200, although for some cases, the distance becomes constant at 100. The only noticeable difference is that the values for the distances when the number of individuals is very high (750,100) does not increase, rather it seems to keep ever so slightly decreasing.

With regards with number of generations(3.13.6), once again, as expected, there is a number of individuals from which the change in the result is almost insignificant. That point, as can be observed, is 200 individuals, the same as the other representation. One difference is that the values obtained from 750 individuals forward is actually worse in some cases, if not the same, while with the other representation there were some cases in which it improved.

For the elitism(3.13.7), there is no doubt that 0.05 is the best percentage of elitism that can be chosen with this representation. The results are somewhat similar to the previous representation, but the slope at the latest values (0.5 forward) is not so steep

Lately, the result of the crossover and mutation (3.13.8) test is daunting. It was repeated, in case it was somehow erroneous, but the same graph was obtained.

## 2.2 Specific tests

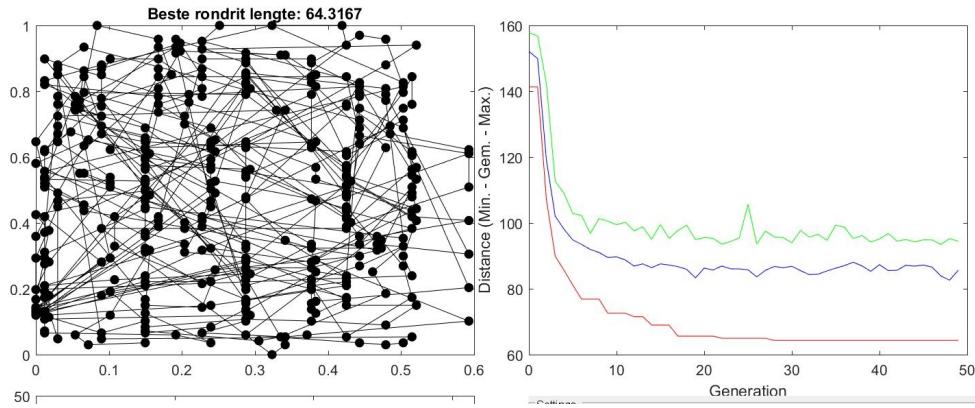
The specific tests are separated in 2 phases.

First phase, study the impact of the best parameter values seen in the general tests, for each representation individually. The second phase corresponds to the comparison between the representation results, first with the base case, and then with the best result obtained. All the tests have been made with the benchmark dataset called bcl380.tsp.

### 2.2.1 Original code

The base values are the same as with the general case. [Number of individuals, generations, percentage of elitism, of crossover and mutation] = [50,50,5%,95%, 5%]

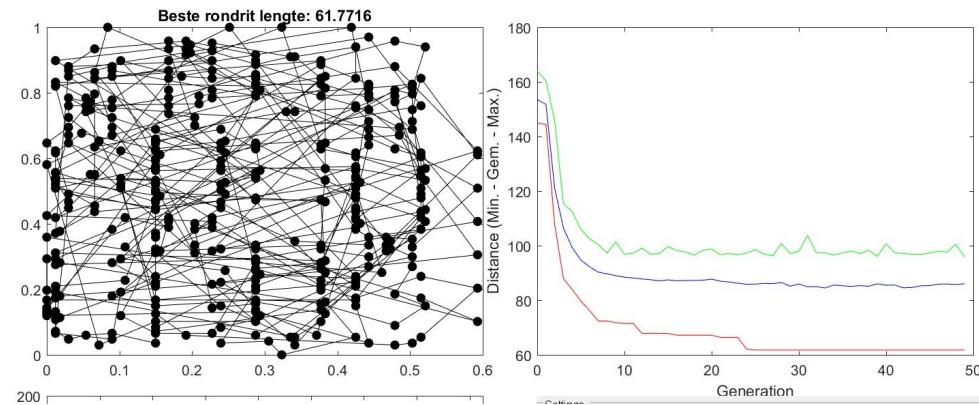
The result obtained is



The test was executed in 12.66 sec

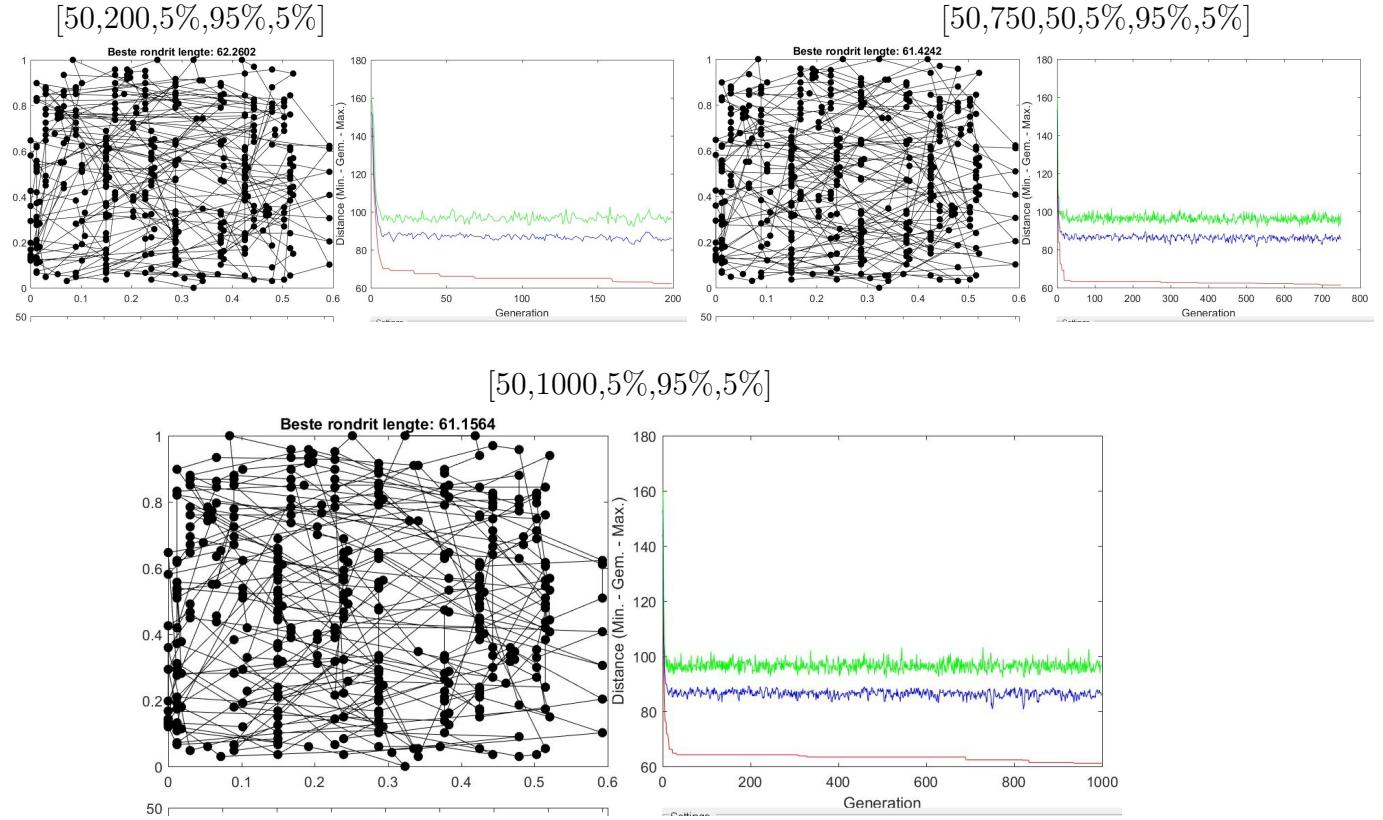
200 was the number of individuals that was deemed to be appropriate. The test, keeping all other values, but changing just the number of individuals is:

[Nind, gens, elitism, crossover, mutation] =[200,50,5%,95%,5%]



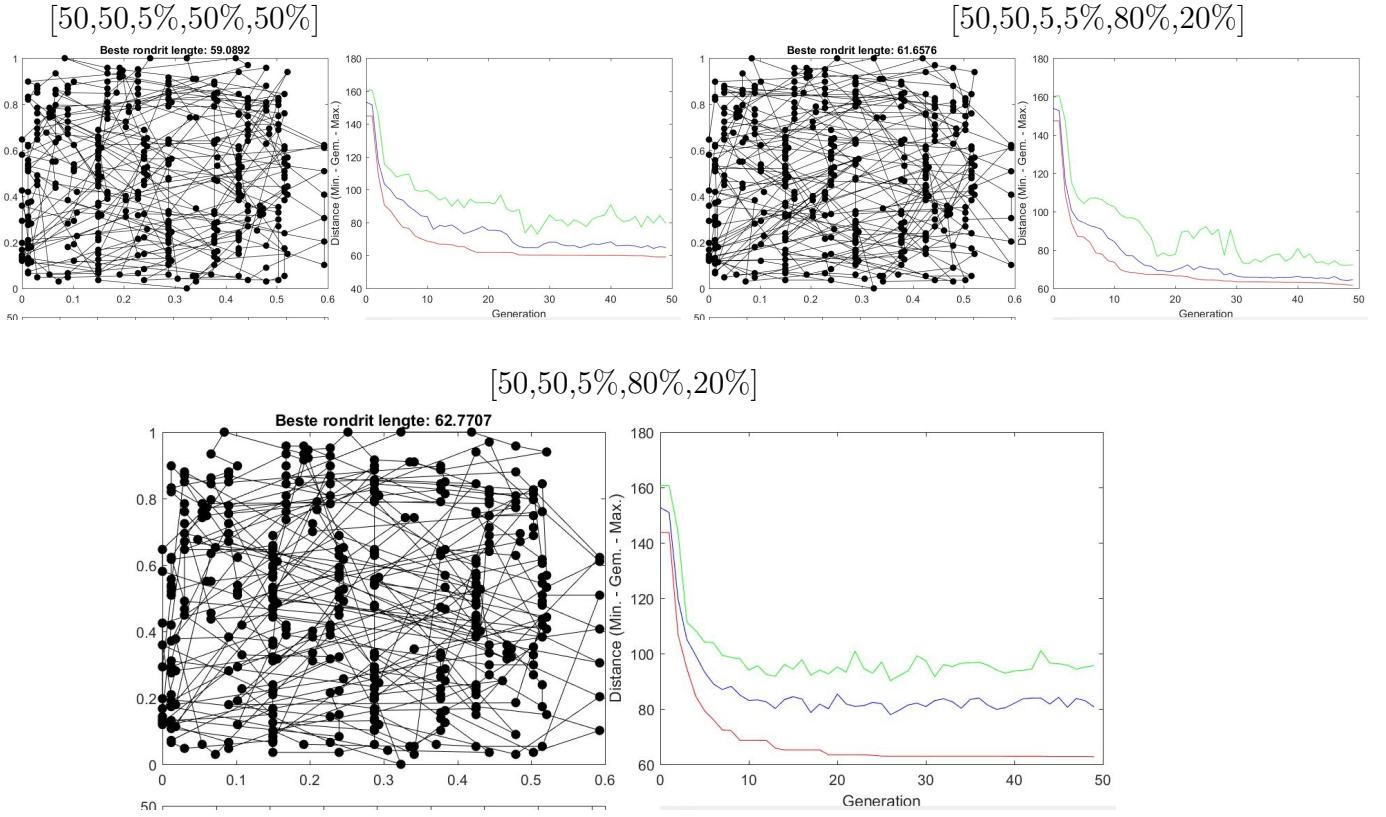
We can see that the minimum distance has decreased, from 64 to 61, not a big decrease, but significant enough. Increasing the number of individuals to 200 is then to be considered a good measure. Timewise, the test was executed in 31.61 seconds. More than twice the time for the first, which, given the increase in the number of individuals, is not out of the expected.

For the next test, this time the number of generations has been increased. As previously stated, the best number was 200, but a higher number was also suitable for some cases. We tried, respectively, with 200, 750, and 1000 generations, thus having



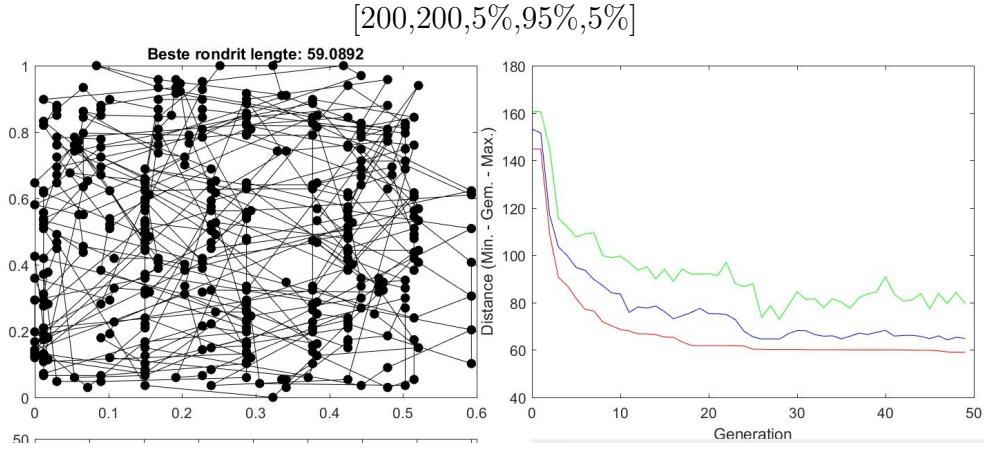
We can observe that the result is slightly better, with each increment of generations, but the cost is excessive, when it comes to time. The times for the tests are 46.01, 171.67, and 233.85 seconds, which means, 4, 13.5 and 18.5 times more than the base case.

As the elitism parameter was abundantly clear that was to be kept at 0.05 (or up to 0.1 at most), and it is already the value for the base case, there is no specific test for the elitism. There is, however, for the percentage of crossover and mutation. Since the result was a bit unexpected, we did not only try with the apparent best result (0.5 percentage of each), but with cases of 0.2 crossover — 0.8 mutation, and viceversa. The results for the tests are

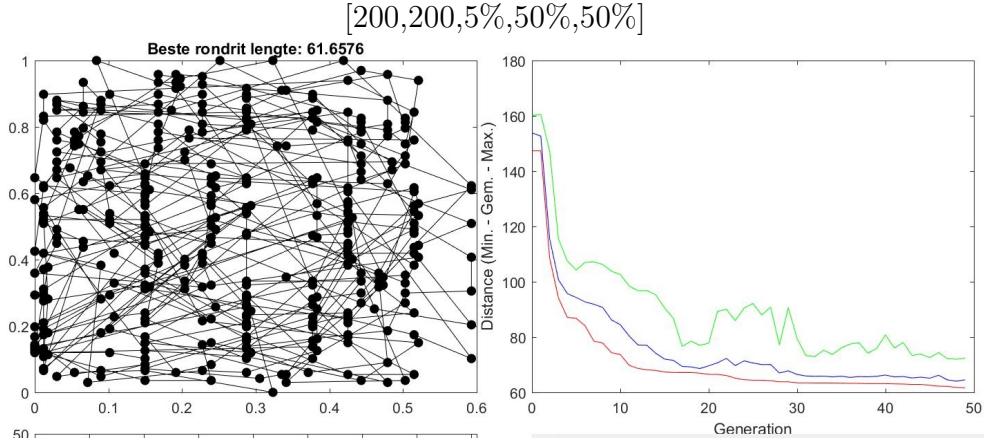


The test confirms the results obtained in the general test. The best ratio of crossover—mutation is 50%—50%, since, out of the 3 configurations, it has the best result, while all of them are over the base case. Although not as relevant in this case, the times of the tests are equal or even lower than the original, 11.3, 9.71, 12.92 seconds respectively.

Finally, the combination of the good results is what made them get outstanding results. In order to avoid bias, the first combination is just modifying the number of individuals, and the number of generations



We can see an improvement, even slightly better than those obtained with the increase in number of individuals or generations alone. The number of generations was chosen to be 200 because we deemed it good enough, and while costly, not as costly as higher quantities.

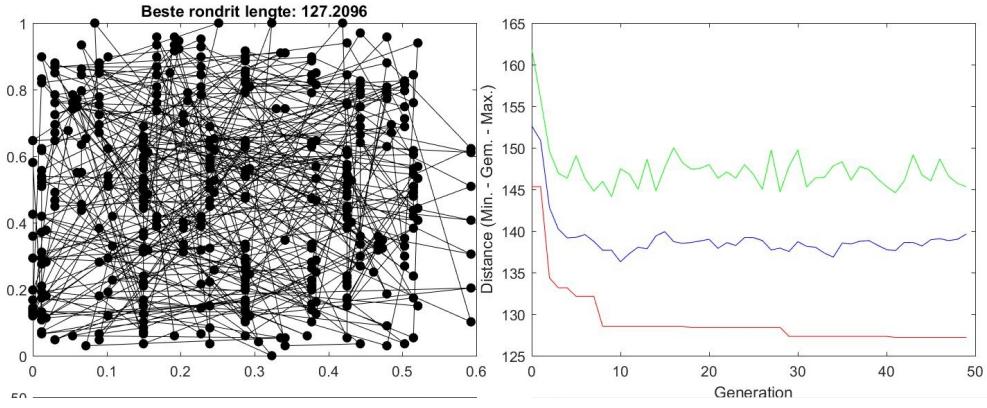


And the final result, when combining every single improvement, is the best of all. The decrease of distance is 30.8%, which could be said to be a great decrease. The time spent on this test was 76.74 seconds, around 6.1 times more than the original, although high, we consider that it is not sufficiently high as to consider it bad.

### 2.2.2 Improved code

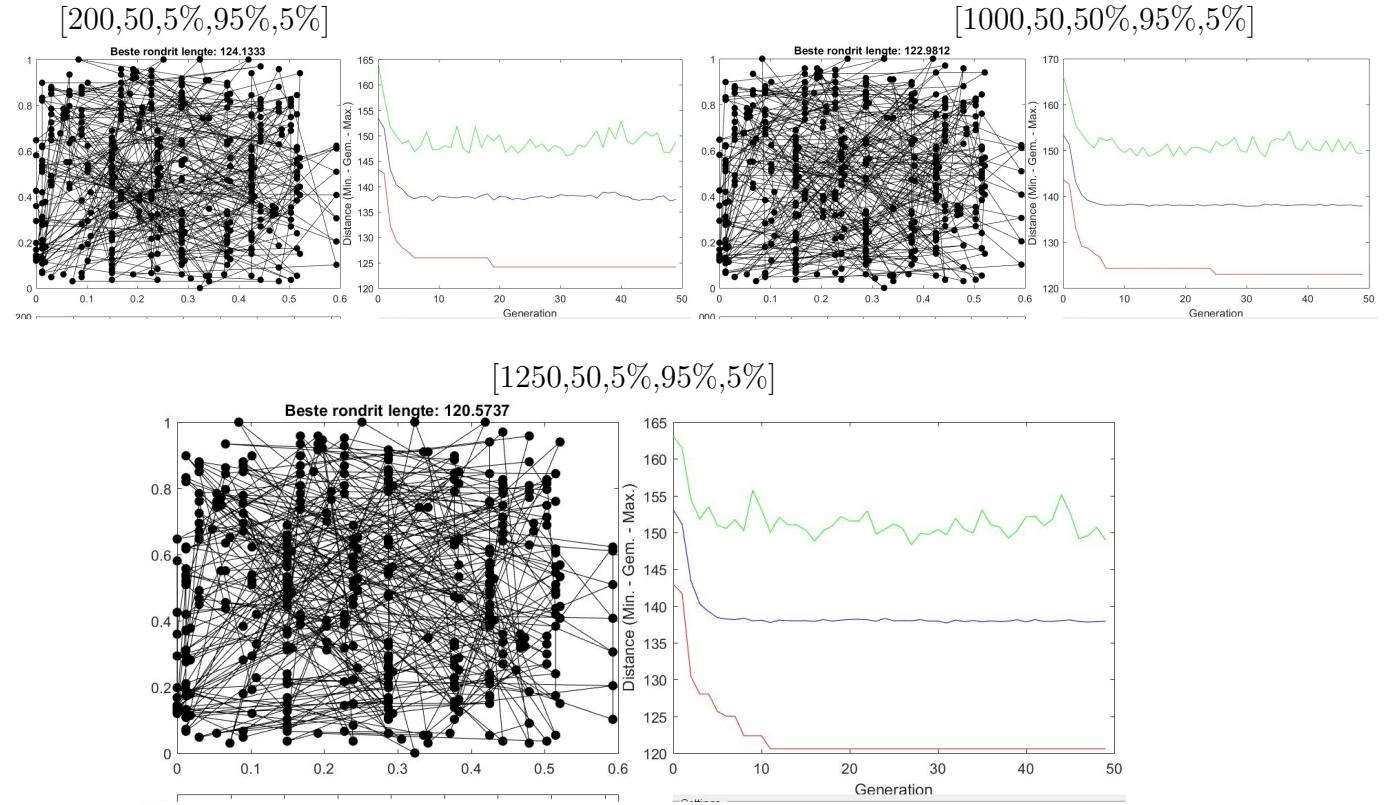
The same structure as the previous representation will be followed. One parameter at a time will be tested, stating the change, after performing a base test

[50,50,5%,95%,5%]



The first noticeable thing that we can observe here is that the distance is far higher than the adjacency representation, although looking at the time, it is better, since it takes only 6.88 seconds.

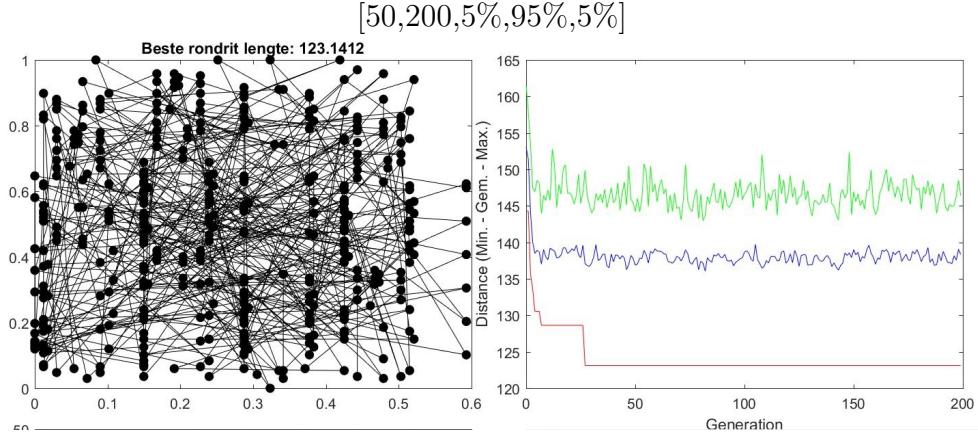
We have the same situation that we had with the number of generations in the previous representation, but this time with the number of individuals. While 200 was the amount with the generally lower distances, higher numbers also performed somewhat ok. Thus we tested for 200, 1000, and 1250.



Although the change is not big, there is improvement, with each increase of individuals. And, what's more, as it is individuals, and not generations that we are increasing now, there is higher cost, but not as high. The times for the tests are 9.08, 29.44, and 37.99 seconds,

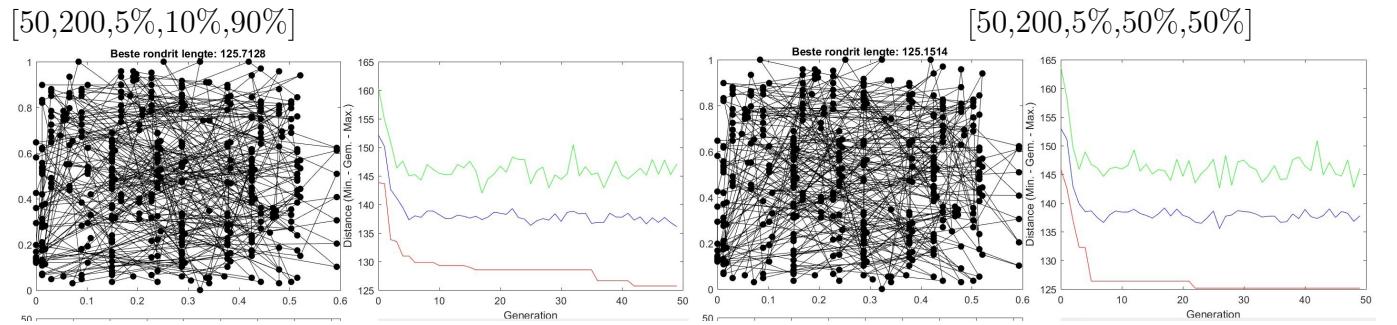
being the last not even 6 times higher. As there is the increase is the highest in the last test (1250 individuals), and the time is not humongously high, that value will be the one to be tested in the combined test.

The general test for the number of generations revealed that the best quantity was 200.



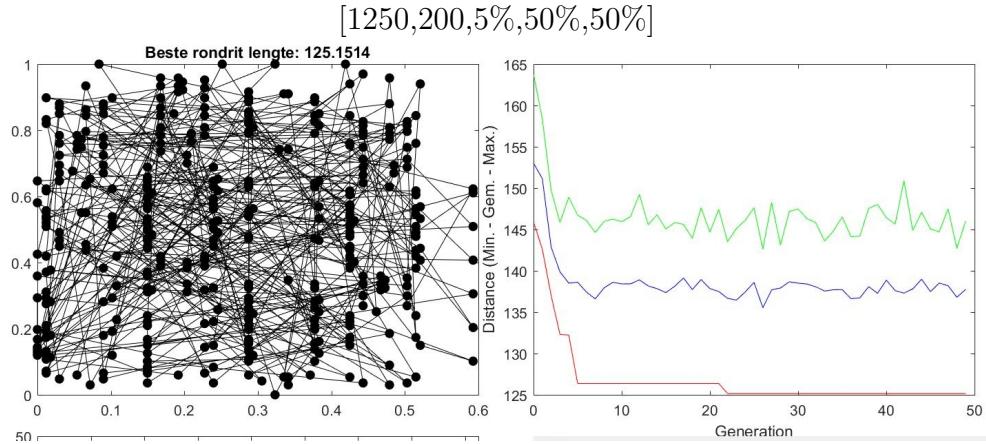
We can observe a slight improvement against the base case, 4 units of distance. Timewise, it is much more demanding that increasing individuals, since the test took 23.73 seconds to end, 3.5 times more than the base case. Any higher number of generations will only hinder the process by making it tediously slow.

As happened in the previous representation tests, the general test for path rep. showed that the value 5% for elitism was without a doubt the best that could be set. So, the last to test is crossover and mutation, and here comes the tricky part for this representation. We found in our general test that no matter what the percentage for mutation or crossover was being tested, the results were almost independant from them. So, given that the base case already tested for a high crossover, and low mutation, the designed tests are, for low crossover and high mutation, and for a 50—50.



Although somewhat better than the base case, the result from one test to the other differ so little that it confirms the result of the general test, stating that, for this representation, given our implementation with our operators, the percentage is not really relevant. But, as it's still better than the base, and the best of the two, the percentages chosen for the combined test are 50%—50%. Obviously, as the number of individuals or generations did not change, the time is almost identical to the base case

For the combined test, in hope to get the best result, this is the test made



Unlike the previous combined test, the big expected improvement is nowhere to be seen. Going from a length of 127 to 120 is just a mere 5.2% of decrease. Furthermore, the combined increase of individuals and generations, given that the former is very high, makes the test to take extremely long compared to the base, going from 6.88 seconds to 141.02 seconds, 20.5 times more.

This can be due to the fact that the crossover operator favors the local minimum and the mutation operator try to explore new paths, but as the mutation operator only changes the position of one number in the sequence of cities, if the percentage of mutation is small, the exploration will be reduced.

### 3 Optional part

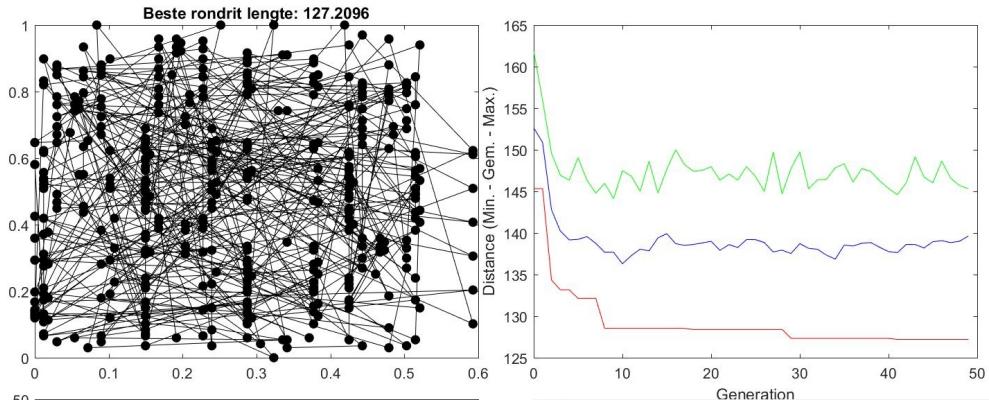
We opted to implement a new survivor selection strategy. The method selected is round robin tournament, which holds pairwise competitions amongst the whole set of individuals (with our implementation), against  $q$  randomly selected, and the selected value for  $q$  is 10, as it is typically recommended [1].

This method consists of holding, in a round robin tournament way, competitions, and keeping the  $\mu$  better individuals. The code for this implementation can be found in the appendix, in 3.12, `select_rr`, where the implementation for the round robin tournament is, and also, some minor modifications to `tspgui`, and `run_ga` were necessary, in order to make it work with both elitism and selection, depending on the value passed as parameter. For the test, `test.m` was modified, and now includes an option to perform the optional tests.

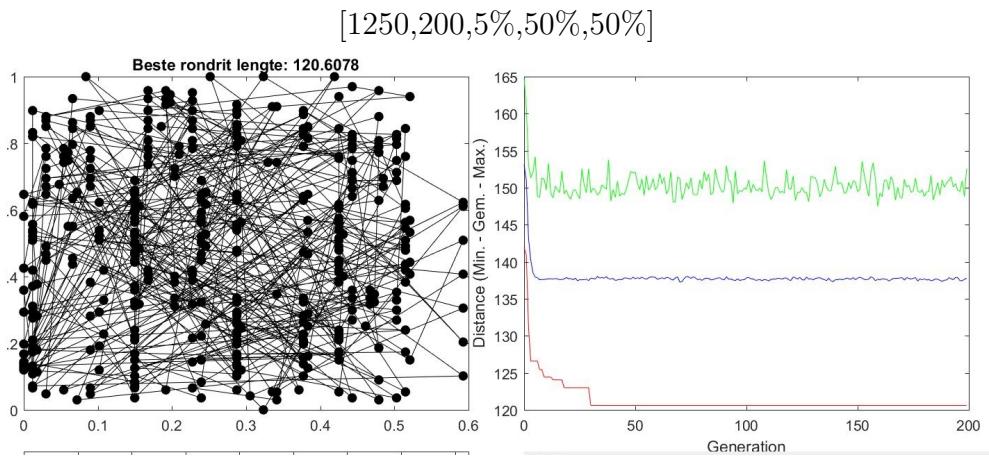
The tests made for this implementation, as it uses the crossover we implemented, we decided to test against the base case of said implementation.

As a reminder, here is the result for the base case

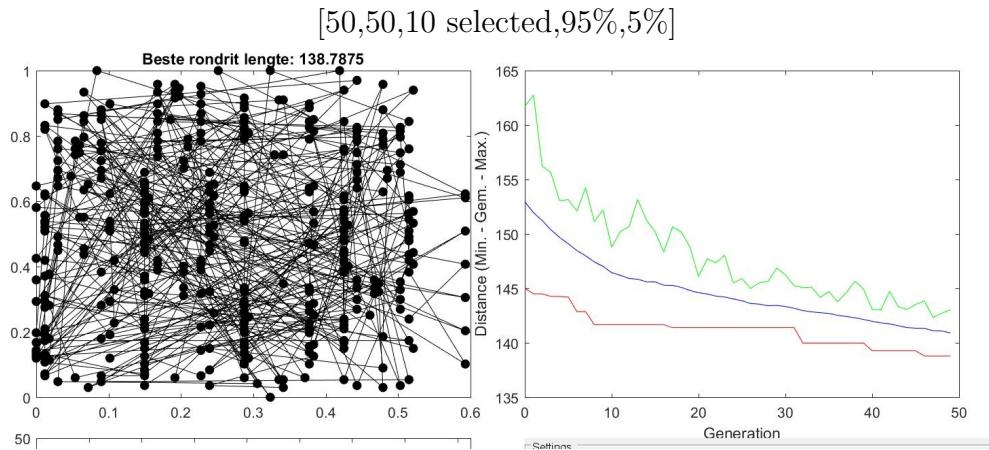
[50,50,5%,95%,5%]



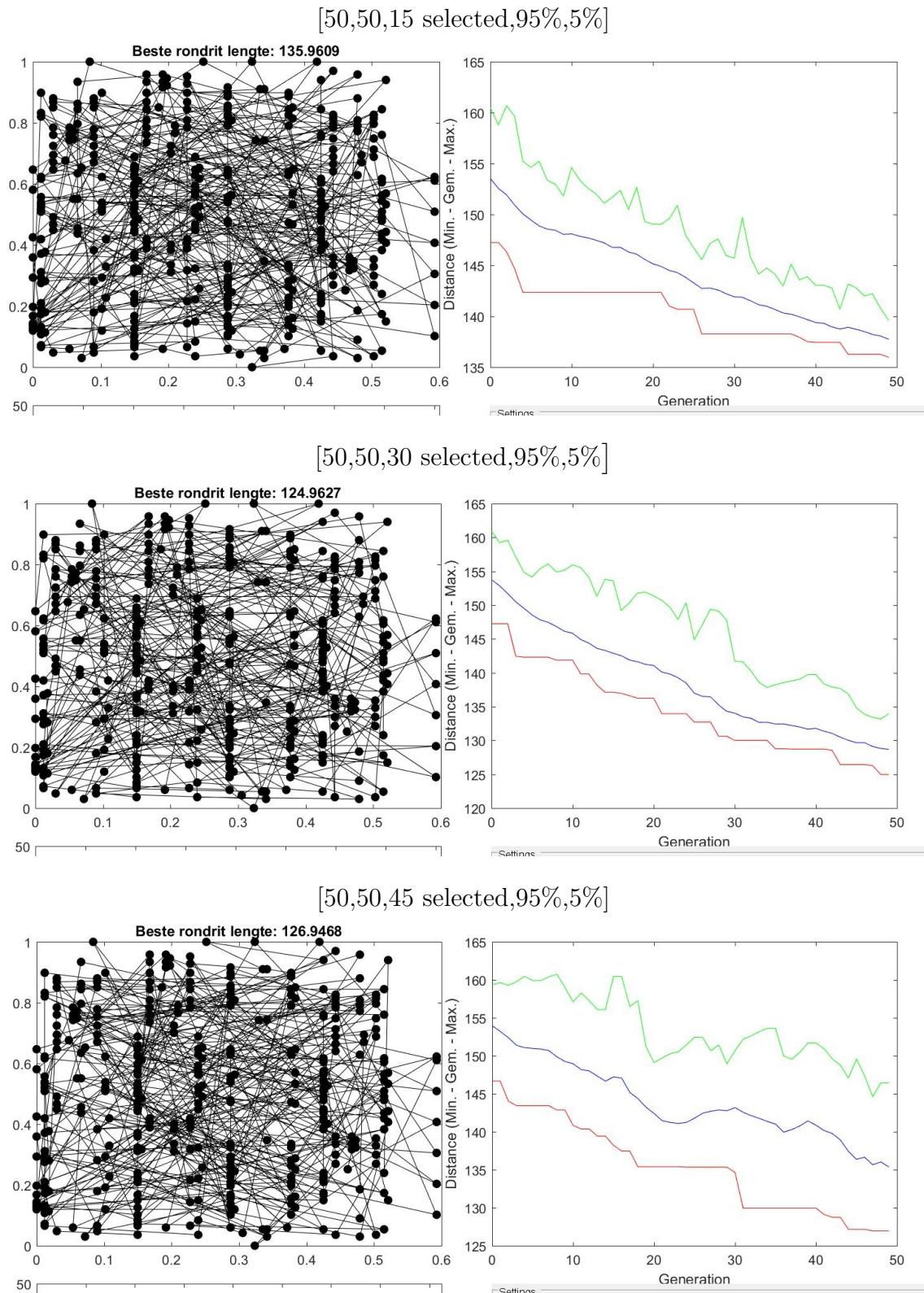
And, the best result obtained after modifying it, with the "best" parameters, according to our general tests

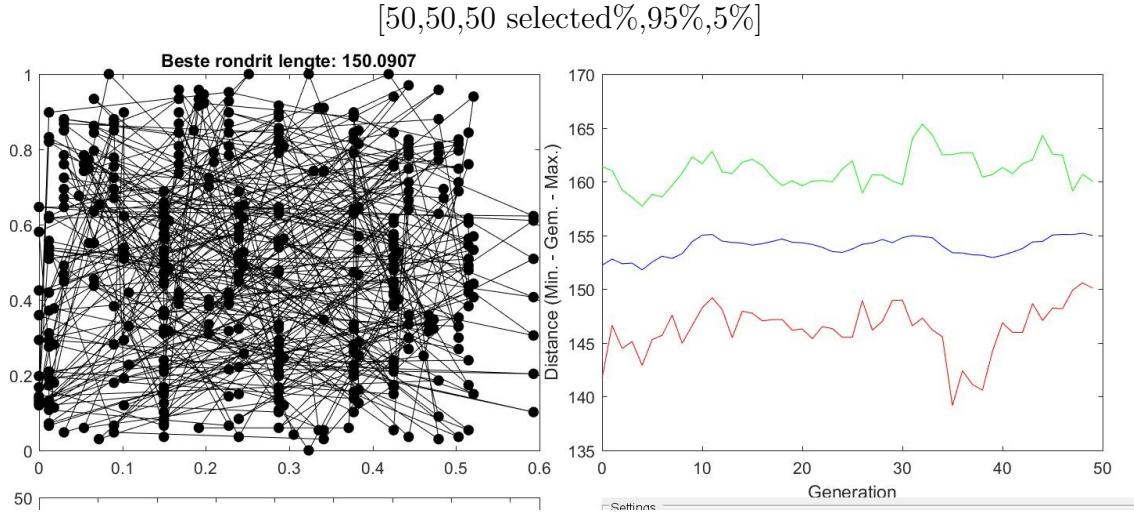


As can be seen, the new selection method started with a worse result, having the same parameters as the base case, only with the % of elitism changed to the number of selected individuals, 10



The only parameter that we can test for is the number of selected individuals from the tournament, and we did so, with 10 (the previous graph), 15,30, 45 and 50





As we can see, with 15 individuals the result is better, but the best outcome comes when the number of individuals is either 30 (the best) or 45 (second best). And, as expected, using all 50 individuals does not only not improve, but actually worsens the result, as it modifies all individuals, no good result is keep from generation to generation. Comparing the time spent on these tests, around 5.5-5.8 each, it is already less time than the average of the base case with elitism, 6.88. Regarding the improvement, when tuning the elitism, the result barely improved at all, but looking at the results with this new selection method, only modifying the number of individuals selected gives us an improvement of 9.96%, which is already more than the "best" solution obtained by tuning all parameters when the selection method was elitism. It could be concluded that this method is better for this problem.

## References

- [1] A.E. Eiben, James E Smith. *Introduction to Evolutionary Computing*. Springer
- [2] P. Larrañaga, C.M.H. Kuijpers, R.H. Murga, I. Inza, S. Dizdarevic *Genetic algorithms for the travelling salesman problem: A review of representations and operators*. University of the Basque Country
- [3] Dirk Roose *Genetic algorithms lectures and slides* KU Leuven
- [4] mnemstudio.org *Genetic algorithms mutations* <http://mnemstudio.org/genetic-algorithmsmutation.htm>

## 4 Appendix

### 4.1 tsp\_ImprovePopulation.m

```
1 % tsp_ImprovePopulation.m
2 % Author: Mike Matton
3 %
4 % This function improves a tsp population by removing local loops
5 % from
6 % each individual.
7 %
8 % Syntax: improvedPopulation = tsp_ImprovePopulation( popsize ,
9 % ncities , pop , improve , dists )
10 %
11 % Input parameters:
12 %   popsize           - The population size
13 %   ncities            - the number of cities
14 %   pop                - the current population (adjacency
15 %                         representation)
16 %   improve             - Improve the population (0 = no improvement
17 %                         , <>0 = improvement)
18 %   dists               - distance matrix with distances between the
19 %                         cities
20 %
21 % Output parameter:
22 %   improvedPopulation - the new population after loop removal (
23 %                         if improve
24 %                                     <> 0 , else the unchanged population).
25 %
26 function newpop = tsp_ImprovePopulation( popsize , ncities , pop ,
27 %                                         improve , dists )
28 %
29 if (improve)
30   for i=1:popsize
31 %
32     result = improve_path( ncities , pop(i,:) , dists );
33 %
34     pop(i,:) = path2adj( result );
35 %
36   end
37 end
38 %
39 newpop = pop;
```

## 4.2 run\_ga.m

```

1 function run_ga(x, y, NIND, MAXGEN, NVAR, SELECTION,
2     STOP_PERCENTAGE, PR_CROSS, PR_MUT, CROSSOVER, LOCALLOOP, ah1 ,
3     ah2 , ah3)
4 % usage: run_ga(x, y,
5 %                 NIND, MAXGEN, NVAR,
6 %                 SELECTION, STOP_PERCENTAGE,
7 %                 PR_CROSS, PR_MUT, CROSSOVER,
8 %                 ah1 , ah2 , ah3)
9 %
10 %
11 % x, y: coordinates of the cities
12 % NIND: number of individuals
13 % MAXGEN: maximal number of generations
14 %
15 % MODIFIED %%%%%%%%%%%%%%
16 % SELECTION: if elitism: percentage of elite population , else ,
17 %               it 's mu, quantity of individuals to be selected
18 % MODIFIED %%%%%%%%%%%%%%
19 %
20 %
21 % STOP_PERCENTAGE: percentage of equal fitness (stop criterium)
22 % PR_CROSS: probability for crossover
23 % PR_MUT: probability for mutation
24 % CROSSOVER: the crossover operator
25 % calculate distance matrix between each pair of cities
26 % ah1 , ah2 , ah3: axes handles to visualise tsp
27 % {NIND MAXGEN NVAR SELECTION STOP_PERCENTAGE PR_CROSS PR_MUT
28 %   CROSSOVER LOCALLOOP} ;
29 %
30
31 tic ;
32 if (SELECTION<=1 && SELECTION>=0)
33     GGAP = 1 - SELECTION;
34 end
35 mean_fits=zeros(1 ,MAXGEN+1);
36 worst=zeros(1 ,MAXGEN+1);
37 Dist=zeros(NVAR,NVAR) ;
38 for i=1:size(x,1)
39     for j=1:size(y,1)
40         Dist(i ,j )=sqrt((x( i)-x( j ))^2+(y( i)-y( j ))^2);
41     end
42 end
43 % initialize population
44 Chrom=zeros(NIND,NVAR) ;

```

```

41 for row=1:NIND
42     %Chrom( row , : )=path2adj( randperm(NVAR) );
43     Chrom( row , : )=randperm(NVAR);
44 end
45 gen=0;
46 % number of individuals of equal fitness needed to stop
47 stopN=ceil(STOP_PERCENTAGE*NIND);
48 % evaluate initial population
49 ObjV = tspfun(Chrom, Dist);
50 best=zeros(1,MAXGEN);
51 % generational loop
52 while gen<MAXGEN
53     sObjV=sort(ObjV);
54     best( gen+1)=min(ObjV);
55     minimum=best( gen+1);
56     mean_fits( gen+1)=mean(ObjV);
57     worst( gen+1)=max(ObjV);
58     for t=1:size(ObjV,1)
59         if (ObjV( t )==minimum)
60             break;
61         end
62     end
63
64 %visualizeTSP (x,y,adj2path(Chrom(t,:)), minimum, ah1,
65 %gen, best, mean_fits, worst, ah2, ObjV, NIND, ah3);
66 visualizeTSP(x,y,Chrom(t,:), minimum, ah1, gen, best,
67 mean_fits, worst, ah2, ObjV, NIND, ah3);
68
69 if (sObjV(stopN)-sObjV(1) <= 1e-15)
70     break;
71 end
72 %assign fitness values to entire population
73 FitnV=ranking(ObjV);
74 %select individuals for breeding
75 if (SELECTION <=1)
76     SelCh=select( 'sus' , Chrom, FitnV, SELECTION);
77 else
78     SelCh=select_rr( 'sus' , Chrom, FitnV, SELECTION);
79 end
80 %recombine individuals (crossover)
81 SelCh = recombin(CROSSOVER, SelCh, PR_CROSS);
82 %SelCh=mutateTSP( 'inversion' , SelCh ,PR_MUT);
83 SelCh=mutateTSP( 'insertion' , SelCh ,PR_MUT); % <-- line
84     changed, now insertion mutation is used
85 %evaluate offspring, call objective function

```

```

83     ObjVSel = tspfun( SelCh , Dist ) ;
84     %reinsert offspring into population
85     [ Chrom , ObjV ]=reins( Chrom , SelCh , 1 , 1 , ObjV , ObjVSel ) ;
86
87     Chrom = tsp_ImprovePopulation( NIND , NVAR , Chrom ,
88                                     LOCALLOOP , Dist ) ;
89     %increment generation counter
90     gen=gen+1;
91
92 end
93 toc ;
94 minimum
end

```

### 4.3 insertion.m

```

1 % low level function for TSP mutation
2 % Representation is an integer specifying which encoding is used
3 % 1 : adjacency representation
4 % 2 : path representation
5 %
6
7 function NewChrom = insertion( OldChrom )
8
9     NewChrom = OldChrom ;
10    % select two positions in the tour
11    rndi = zeros(1 , 2) ;
12    while rndi(1) == rndi(2)
13        rndi=rand_int(1 , 2 , [1 size(NewChrom , 2)]) ;
14    end
15    rndi = sort(rndi) ;
16
17    % get the value of the first random position
18    temp = NewChrom(rndi(1)) ;
19    % insert this value in the second random position
20    NewChrom = insertAt( NewChrom , temp , rndi(2) ) ;
21    % remove the first random position
22    NewChrom( rndi(1) ) = [] ;
23    % End of function
24
25
26 function arrOut = insertAt( arr , val , index )
27     if index == numel(arr)+1
28         arrOut = [ arr val ] ;

```

```

29 |     else
30 |         arrOut = [ arr(1:index-1) val arr(index:end)];
31 |     end
32 | end

```

## 4.4 order\_crossover.m

```

33 NewChrom( row+1,:) = MatrixChrom( 2 , : );
34 else
35 NewChrom( row,: ) = OldChrom( row ,: );
36 NewChrom( row+1,: ) = OldChrom( row+1,: );
37 end
38 end
39
40 if rem( rows ,2) ~= 0
41 NewChrom( rows ,:) =OldChrom( rows ,: );
42 end
43
44 % End of function

```

## 4.5 order\_low\_level.m

```

1 % low level function for calculating an offspring
2 % given 2 parent in the Parents – agrument
3 % Parents is a matrix with 2 rows , each row
4 % represent the genocode of the parent
5 %
6 % Returns a matrix containing the offspring
7
8
9 function Offspring=order_low_level( Parents )
10
11 cols = size( Parents ,2 );
12
13 Offspring=zeros(2 ,cols );
14
15 start_index = rand_int(1 , 1 , [1 , cols - 1]);
16 end_index = rand_int(1 , 1 , [start_index + 1 , cols ]);
17
18 Offspring (1 , start_index:end_index) = Parents (2 , start_index:
19 end_index );
20 Offspring (2 , start_index:end_index) = Parents (1 , start_index:
21 end_index );
22
23 for off=1:2
24 Buff = Parents (off ,: );
25 Buff = [ Buff(end_index+1:end) , Buff(1:end_index )];
26
27 members = ismember( Buff , Offspring (off , :));
Buff(members == 1) = 0;

```

```

28
29     ii = 1;
30     X = find(Buff);
31     for jj=1:start_index - 1
32         if Buff(X(ii)) ~= 0
33             Offspring(off, jj) = Buff(X(ii));
34             Buff(X(ii)) = 0;
35             ii = mod(ii, cols) + 1;
36         end
37     end
38
39     ii = 1;
40     X = find(Buff);
41     for jj=end_index + 1:cols
42         if Buff(X(ii)) ~= 0
43             Offspring(off, jj) = Buff(X(ii));
44             Buff(X(ii)) = 0;
45             ii = mod(ii, cols) + 1;
46         end
47     end
48     %Offspring(off, end_index+1:end) = Buff(start_index:end);
49     %Offspring(off, 1:start_index - 1) = Buff(1:start_index -
50     1);
51
51 % end function

```

## 4.6 tspgui.m

```

1 Crossover = 'order_crossover';
2 crossover = uicontrol(ph, 'Style', 'popupmenu', 'String', {'',
3     'order_crossover'}, 'Value', 1, 'Position', [10 50 130 20], 'Callback', @crossover_Callback);

```

## 4.7 tspfun.m

```

1 %
2 % ObjVal = tspfun(Phen, Dist)
3 % Implementation of the TSP fitness function
4 % Phen contains the phenocode of the matrix coded in path
5 % representation
6 % Dist is the matrix with precalculated distances between each
    pair of cities

```

```

7 % ObjVal is a vector with the fitness values for each candidate
8 % tour
9 %
10
11 function ObjVal = tspfun(Phen, Dist)
12 % the objective function works with adjacency representation.
13 % In this
14 % version , path representation is used , so the fitness
15 % function should
16 % be adapted. Now, the phenotype is converted to adjacency
17 % representation first , and then , the Objective Value is
18 % computed as it
19 % was computed in the original version .
20 adj = zeros(size(Phen));
21 for row=1:size(Phen)
22     adj(row,:) = path2adj(Phen(row,:));
23 end
24
25
26
27 % End of function

```

## 4.8 mutateTSP.m

```

1 % MUTATETSP.M          (MUTATION for TSP high-level function)
2 %
3 % This function takes a matrix OldChrom containing the
4 % representation of the individuals in the current population ,
5 % mutates the individuals and returns the resulting population .
6 %
7 % Syntax: NewChrom = mutate(MUTF, OldChrom, MutOpt)
8 %
9 % Input parameter:
10 %    MUTF      - String containing the name of the mutation
11 %                  function
12 %    OldChrom  - Matrix containing the chromosomes of the old
13 %                  population . Each line corresponds to one
14 %                  individual .
15 %    MutOpt    - mutation rate
16 %
17 % Output parameter:

```

```

15 % NewChrom - Matrix containing the chromosomes of the
16 % population
17 % after mutation in the same format as OldChrom.
18
19 function NewChrom = mutateTSP(MUT_F, OldChrom, MutOpt)
20
21 % Check parameter consistency
22 if nargin < 2, error('Not_enough_input_parameters'); end
23
24 [rows, ~] = size(OldChrom);
25 NewChrom=OldChrom;
26
27 for r=1:rows
28   if rand<MutOpt
29     NewChrom(r,:)= feval(MUT_F, OldChrom(r,:));
30   end
31 end
32
33 % End of function

```

## 4.9 run\_ga\_test.m

```

1 function minimum=run_ga_test(modality, x, y, NIND, MAXGEN, NVAR,
2   SELECTION, ...
3   STOP_PERCENTAGE, PR_CROSS, PR_MUT, CROSSOVER, LOCALLOOP)
4 % usage: run_ga(x, y,
5 %                 NIND, MAXGEN, NVAR,
6 %                 ELITIST, STOP_PERCENTAGE,
7 %                 PR_CROSS, PR_MUT, CROSSOVER,
8 %                 ah1, ah2, ah3)
9 %
10 % x, y: coordinates of the cities
11 % NIND: number of individuals
12 % MAXGEN: maximal number of generations
13 % ELITIST: percentage of elite population
14 % STOP_PERCENTAGE: percentage of equal fitness (stop criterium)
15 % PR_CROSS: probability for crossover
16 % PR_MUT: probability for mutation
17 % CROSSOVER: the crossover operator
18 % calculate distance matrix between each pair of cities
19 % ah1, ah2, ah3: axes handles to visualise tsp

```

```

20 { modality NIND MAXGEN NVAR SELECTION STOP_PERCENTAGE PR_CROSS
21 PR_MUT CROSSOVER LOCALLOOP};

22
23 if (SELECTION<=1 && SELECTION>=0)
24     GGAP = 1 - SELECTION;
25 end

26
27 mean_fits=zeros(1,MAXGEN+1);
28 worst=zeros(1,MAXGEN+1);
29 Dist=zeros(NVAR,NVAR);
30 for i=1:size(x,1)
31     for j=1:size(y,1)
32         Dist(i,j)=sqrt((x(i)-x(j))^2+(y(i)-y(j))^2);
33     end
34 end
35 % initialize population
36 Chrom=zeros(NIND,NVAR);
37 for row=1:NIND
38     if (modality==1)
39         Chrom(row,:)=randperm(NVAR);
40     else
41         Chrom(row,:)=path2adj(randperm(NVAR));
42     end
43 end
44 gen=0;
45 % number of individuals of equal fitness needed to stop
46 stopN=ceil(STOP_PERCENTAGE*NIND);
47 % evaluate initial population
48 ObjV = tspfun(Chrom, Dist);
49 best=zeros(1,MAXGEN);
50 % generational loop
51 while gen<MAXGEN
52     sObjV=sort(ObjV);
53     best(gen+1)=min(ObjV);
54     minimum=best(gen+1);
55     mean_fits(gen+1)=mean(ObjV);
56     worst(gen+1)=max(ObjV);
57     for t=1:size(ObjV,1)
58         if (ObjV(t)==minimum)
59             break;
60         end
61     end
62 end
63

```

```

64 %visualizeTSP (x ,y ,adj2path (Chrom(t ,:)) , minimum , ah1 ,
65 gen , best , mean_fits , worst , ah2 , ObjV , NIND , ah3 );
66
67 if (sObjV(stopN)-sObjV(1) <= 1e-15)
68     break;
69 end
70 %assign fitness values to entire population
71 FitnV=ranking(ObjV);
72 %select individuals for breeding
73 if (SELECTION <=1)
74     SelCh=select( 'sus' , Chrom , FitnV , SELECTION);
75 else
76     SelCh=select_rr( 'sus' , Chrom , FitnV , SELECTION);
77 end
78
79 %recombine individuals (crossover)
80 SelCh = recombin(CROSSOVER,SelCh,PR_CROSS);
81
82 if (modality==1)
83     SelCh=mutateTSP( 'insertion' ,SelCh ,PR_MUT);
84 else
85     SelCh=mutateTSP( 'inversion' ,SelCh ,PR_MUT);
86 end
87
88 %evaluate offspring , call objective function
89 ObjVSel = tspfun(SelCh ,Dist);
90 %reinsert offspring into population
91 [Chrom , ObjV]=reins(Chrom ,SelCh ,1 ,1 ,ObjV ,ObjVSel);
92
93 Chrom = tsp_ImprovePopulation(NIND , NVAR , Chrom ,
94 LOCALLOOP ,Dist);
95 %increment generation counter
96 gen=gen+1;
end
end

```

## 4.10 tspgui\_test.m

```

1 function tspgui_test(CROSSOVER, NIND, MAXGEN,SELECTION,PR_CROSS,
2 PR_MUT, ...
3 LOCALLOOP, testName)
4

```

```

5 %
%oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo%
%
6 if (SELECTION<=1)
7   GGAP=1-SELECTION;    % Generation gap
8   sliderTxt='%_elite';
9   maxSlider=100;
10  minSlider=0;
11  val=round(SELECTION*100);
12 else
13   sliderTxt='#_individuals';
14   maxSlider=NIND;
15   minSlider=10;
16   val=round(SELECTION);
17 end
18
19 STOP_PERCENTAGE=.95;      % percentage of equal fitness individuals
20 % for stopping
% %
%oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo%
%
21
22 % read an existing population
23 % 1 — to use the input file specified by the filename
24 % 0 — click the cities yourself, which will be saved in the file
25 % called
26 %USE_FILE=0;
27 %FILENAME='data/cities.xy';
28 %if (USE_FILE==0)
29 %  % get the input cities
30 %  fg1 = figure(1); clf;
31 %  %subplot(2,2,2);
32 %  axis([0 1 0 1]);
33 %  title(NVAR);
34 %  hold on;
35 %  x=zeros(NVAR,1);y=zeros(NVAR,1);
36 %  for v=1:NVAR
37 %    [xi,yi]=ginput(1);
38 %    x(v)=xi;
39 %    y(v)=yi;
40 %    plot(xi,yi,'ko','MarkerFaceColor','Black');
41 %    title(NVAR-v);
42 %  end
43 %  hold off;
44 %  set(fg1,'Visible','off');

```

```

44 % dlmwrite(FILENAME,[ x y ],'\t') ;
45 %else
46 % XY=dlmread(FILENAME,'\'\t') ;
47 % x=XY(:,1) ;
48 % y=XY(:,2) ;
49 %end
50
51 % load the data sets from the benchmark list
52 benchmarks = dir('TSPBenchmark/');
53 datasets=cell( size(benchmarks,1)-2,1);
54 for i=1:size(datasets,1)
55     datasets{i} = benchmarks(i+2).name;
56 end
57
58 % start with first dataset
59 data = load(['TSPBenchmark/bcl380.tsp']);
60 x=data(:,1)/max([data(:,1);data(:,2)]);
61 y=data(:,2)/max([data(:,1);data(:,2)]);
62 NVAR=size(data,1);
63
64 % initialise the user interface
65 fh = figure('Visible','off','Name','TSP-Tool','Position',
66             [0,0,1024,768]);
67 ah1 = axes('Parent',fh,'Position',[.1 .55 .4 .4]);
68 plot(x,y,'ko')
69 ah2 = axes('Parent',fh,'Position',[.55 .55 .4 .4]);
70 axes(ah2);
71 xlabel('Generation');
72 ylabel('Distance_(Min._-Gem._-Max.)');
73 ah3 = axes('Parent',fh,'Position',[.1 .1 .4 .4]);
74 axes(ah3);
75 title('Histogram');
76 xlabel('Distance');
77 ylabel('Number');
78
78 ph = uipanel('Parent',fh,'Title','Settings','Position',[.55 .05
79 .45 .45]);
80 datasetpopuptxt = uicontrol(ph,'Style','text','String','Dataset',
81 'Position',[0 260 130 20]);
80 datasetpopup = uicontrol(ph,'Style','popupmenu','String',datasets,
81 'Value',1,'Position',[130 260 130 20],'Callback',
81 @datasetpopup_Callback);
81 llooppopuptxt = uicontrol(ph,'Style','text','String','Loop-
81 Detection','Position',[260 260 130 20]);

```

```

82 llooppopup = uicontrol(ph, 'Style', 'popupmenu', 'String', { 'off' , 'on' ,
83     }, 'Value', 1, 'Position', [390 260 50 20], 'Callback',
84     @llooppopup_Callback);
85 ncitiesslidertxt = uicontrol(ph, 'Style', 'text', 'String', '#_Cities',
86     , 'Position', [0 230 130 20]);
87 %ncitiesslider = uicontrol(ph, 'Style', 'slider', 'Max', 128, 'Min', 4,
88     'Value', NVAR, 'Sliderstep', [0.012 0.05], 'Position', [130 230 150
89     20], 'Callback', @ncitiesslider_Callback);
90 ncitiessliderv = uicontrol(ph, 'Style', 'text', 'String', NVAR,
91     'Position', [280 230 50 20]);
92 nindslidertxt = uicontrol(ph, 'Style', 'text', 'String', '#_
93     Individuals', 'Position', [0 200 130 20]);
94 nindslider = uicontrol(ph, 'Style', 'slider', 'Max', 1000, 'Min', 10,
95     'Value', NIND, 'Sliderstep', [0.001 0.05], 'Position', [130 200 150
96     20], 'Callback', @nindslider_Callback);
97 nindsliderv = uicontrol(ph, 'Style', 'text', 'String', NIND, 'Position',
98     ,[280 200 50 20]);
99 genslidertxt = uicontrol(ph, 'Style', 'text', 'String', '#_Generations
100    , 'Position', [0 170 130 20]);
101 genslider = uicontrol(ph, 'Style', 'slider', 'Max', 1000, 'Min', 10,
102     'Value', MAXGEN, 'Sliderstep', [0.001 0.05], 'Position', [130 170 150
103     20], 'Callback', @genslider_Callback);
104 gensliderv = uicontrol(ph, 'Style', 'text', 'String', MAXGEN, 'Position
105    ,[280 170 50 20]);
106 mutslidertxt = uicontrol(ph, 'Style', 'text', 'String', 'Pr._Mutation',
107     , 'Position', [0 140 130 20]);
108 mutslider = uicontrol(ph, 'Style', 'slider', 'Max', 100, 'Min', 0, 'Value
109     , round(PR MUT*100), 'Sliderstep', [0.01 0.05], 'Position', [130
110     140 150 20], 'Callback', @mutslider_Callback);
111 mutsliderv = uicontrol(ph, 'Style', 'text', 'String', round(PR MUT
112     *100), 'Position', [280 140 50 20]);
113 crossslidertxt = uicontrol(ph, 'Style', 'text', 'String', 'Pr.-
114     Crossover', 'Position', [0 110 130 20]);
115 crossslider = uicontrol(ph, 'Style', 'slider', 'Max', 100, 'Min', 0,
116     'Value', round(PR CROSS*100), 'Sliderstep', [0.01 0.05], 'Position'
117     ,[130 110 150 20], 'Callback', @crossslider_Callback);
118 crosssliderv = uicontrol(ph, 'Style', 'text', 'String', round(PR CROSS
119     *100), 'Position', [280 110 50 20]);
120 elitslidertxt = uicontrol(ph, 'Style', 'text', 'String', sliderTxt,
121     'Position', [0 80 130 20]);
122 elitslider = uicontrol(ph, 'Style', 'slider', 'Max', maxSlider, 'Min',
123     minSlider, 'Value', val, 'Sliderstep', [0.01 0.05], 'Position', [130
124     80 150 20], 'Callback', @elitslider_Callback);
125 elitsliderv = uicontrol(ph, 'Style', 'text', 'String', val, 'Position
126     ,[280 80 50 20]);

```

```

101 crossover = uicontrol(ph , 'Style' , 'popupmenu' , 'String' ,{ 'order_crossover'}, 'Value' ,1 , 'Position' ,[10 50 130 20] , 'Callback' ,@crossover_Callback);
102 %inputbutton = uicontrol(ph , 'Style' , 'pushbutton' , 'String' , 'Input' , 'Position' ,[55 10 70 30] , 'Callback' ,@inputbutton_Callback);
103 runbutton = uicontrol(ph , 'Style' , 'pushbutton' , 'String' , 'START' , 'Position' ,[0 10 50 30] , 'Callback' ,@runbutton_Callback);
104
105 set(fh , 'Visible' , 'on');
106
107 %%%%%%
108 %Added for the tests
109 runbutton_Callback;
110 saveas(fh , testName , 'jpg');
111 close(fh);
112 %%%%%%
113
114 function datasetpopup_Callback(hObject,~)
115     dataset_value = get(hObject , 'Value');
116     dataset = datasets{dataset_value};
117     % load the dataset
118     data = load(['datasets/' dataset]);
119     x=data(:,1)/max([data(:,1);data(:,2)]);y=data(:,2)/max([
120         data(:,1);data(:,2)]);
121     %x=data(:,1);y=data(:,2);
122     NVAR=size(data,1);
123     set(ncitiessliderv , 'String' , size(data,1));
124     axes(ah1);
125     plot(x,y,'ko')
126 end
127 function llooppopup_Callback(hObject,~)
128     lloop_value = get(hObject , 'Value');
129     if lloop_value==1
130         LOCALLOOP = 0;
131     else
132         LOCALLOOP = 1;
133     end
134 function ncitiesslider_Callback(hObject,~)
135     fslider_value = get(hObject , 'Value');
136     slider_value = round(fslider_value);
137     set(hObject , 'Value' , slider_value);
138     set(ncitiessliderv , 'String' , slider_value);
139     NVAR = round(slider_value);
140 end

```

```

141 function nindslider_Callback(hObject,~)
142     fslider_value = get(hObject,'Value');
143     slider_value = round(fslider_value);
144     set(hObject,'Value',slider_value);
145     set(nindsliderv,'String',slider_value);
146     NIND = round(slider_value);
147 end
148 function genslider_Callback(hObject,~)
149     fslider_value = get(hObject,'Value');
150     slider_value = round(fslider_value);
151     set(hObject,'Value',slider_value);
152     set(gensliderv,'String',slider_value);
153     MAXGEN = round(slider_value);
154 end
155 function mutslider_Callback(hObject,~)
156     fslider_value = get(hObject,'Value');
157     slider_value = round(fslider_value);
158     set(hObject,'Value',slider_value);
159     set(mutsliderv,'String',slider_value);
160     PRMUT = round(slider_value)/100;
161 end
162 function crossslider_Callback(hObject,~)
163     fslider_value = get(hObject,'Value');
164     slider_value = round(fslider_value);
165     set(hObject,'Value',slider_value);
166     set(crosssliderv,'String',slider_value);
167     PR_CROSS = round(slider_value)/100;
168 end
169 function elitslider_Callback(hObject,~)
170     fslider_value = get(hObject,'Value');
171     slider_value = round(fslider_value);
172     set(hObject,'Value',slider_value);
173     set(elitsliderv,'String',slider_value);
174     if (SELECTION<=1)
175         SELECTION = round(slider_value)/100;
176         GGAP = 1-SELECTION;
177     else
178         SELECTION = round(slider_value);
179     end
180 end
181 function crossover_Callback(hObject,~)
182     crossover_value = get(hObject,'Value');
183     crossovers = get(hObject,'String');
184     CROSSOVER = crossovers(crossover_value);
185     CROSSOVER = CROSSOVER{1};

```

```

186 end
187 function runbutton_Callback(~,~)
188     %set( ncitiesslider , 'Visible' , 'off' );
189     set(nindslider , 'Visible' , 'off' );
190     set(genslider , 'Visible' , 'off' );
191     set(mutslider , 'Visible' , 'off' );
192     set(crossslider , 'Visible' , 'off' );
193     set(elitslider , 'Visible' , 'off' );
194     run_ga(x, y, NIND, MAXGEN, NVAR, SELECTION,
195             STOP_PERCENTAGE, PR_CROSS, PR_MUT, CROSSOVER, LOCALLOOP
196             , ah1, ah2, ah3);
197     end_run();
198 end
199 function inputbutton_Callback(~,~)
200     [x,y] = input_cities(NVAR);
201     axes(ah1);
202     plot(x,y, 'ko')
203 end
204 function end_run()
205     %set( ncitiesslider , 'Visible' , 'on' );
206     set(nindslider , 'Visible' , 'on' );
207     set(genslider , 'Visible' , 'on' );
208     set(mutslider , 'Visible' , 'on' );
209     set(crossslider , 'Visible' , 'on' );
210     set(elitslider , 'Visible' , 'on' );
211 end

```

## 4.11 test.m

```

1 %%%%
2 %
3 Modifications:
4
5 run_ga_test --> Now returns a value, minimun, does not use
6 the function visualizeTSP (line ~56), and takes into account which
7 crossover operator is used, and whether the selection for the new
8 offspring
9 is elitism or roundrobin tournament
10
11 tspgui_test --> Now runs automatically the test with the benchmark
12     bcl380
13 configuration, saves and closes the figure

```

```

13 test —> There are 2 sets of tests. First , specific tests , limited
14 in
15 number, made with a purpose. Those tests are run with tspgui-test ,
16 using
17 the dataset from the benchmark bcl380 , and saving the figure.
18 The second set is the generalistic tests , which check the 4
19 different
20 components to be changed (aka: number of individuals , number of
21 generations , elitism , and percentage of crossover and mutation) ,
22 with all
23 the datasets. Each test is made with a certain number of values ,
24 repeated *reps* (variable in the code , currently set to 5) times ,
25 and the
26 mean obtained by that is the value we use for the plots.
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51

```

%}

%%%

%Clear previous existing variables

clear

%Check if folder tests exists , if not , create it

**if** ~exist('tests' , 'dir')

    mkdir('tests');

**end**

%Options for Crossover (depending on the crossover , a

    representation will

    be choosen

%CROSSOVER = 'order\_crossover';

%CROSSOVER = 'xalt\_edges';

% 1 for specific tests (limited tests , with graph saving)

% 2 for benchmark (obtain just the distance)

% 3 for both

%perform\_tests(3 , CROSSOVER);

perform\_optest();

**function** perform\_tests(n , CROSSOVER)

**if** ~exist(strcat('tests/' , CROSSOVER) , 'dir')

```

52     mkdir( strcat( ' tests / ',CROSSOVER) );
53
54
55 %Specific test
56 if(n==1 || n==3)
57
58     %Depending on the representation (crossover choosen), the
59     % data
60     % for the specific test is choosen
61     if(strcmp(CROSSOVER, 'order_crossover'))
62
63         %
64         %%%%%%%%%%%%%%
65
66         NIND=      [50,200,1000,1250,50,50,50,1250];
67         MAXGEN=   [50,50,50,50,200,50,50,200];
68         ELITIST=0.05;
69         PR_CROSS=[.95,.95,.95,.95,.95,.1,.5,.5,.5];
70         PR_MUT=   [.05,.05,.05,.05,.05,.9,.5,.5];
71         LOCALLOOP=1;
72         %
73         %%%%%%%%%%%%%%
74
75
76 else
77
78     %
79     %%%%%%%%%%%%%%
80
81         NIND=      [50,200,50,50,50,50,50,50,200,200];
82         MAXGEN=   [50,50,200,750,1000,50,50,50,200,200];
83         ELITIST=0.05;
84         PR_CROSS=[.95,.95,.95,.95,.95,.5,.20,.80,.95,.5];
85         PR_MUT=   [.05,.05,.05,.05,.05,.05,.05,.05,.05,.5];
86         LOCALLOOP=1;
87         %
88         %%%%%%%%%%%%%%
89
90 end
91
92 %
93 %%%%%%%%%%%%%%

```

```

86 upbound = size(NIND);
87 for i=1:upbound(2)
88     tspgui_test(CROSSOVER, NIND(i), MAXGEN(i), ELITIST(i),
89     ...
90     PR_CROSS(i), PR_MUT(i), LOCALLOOP, ...
91     strcat('tests/', CROSSOVER, '/', 'general_', num2str
92     (i) ) );
93 end
94
95 end %end if (n==1 || n==3)
96
97 %General tests
98 if (n==2 || n==3)
99
100    reps = 5;
101
102    %
103    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
104
105    NIND=[50,100,150,200,500,750,1000];
106    MAXGEN=[50,100,150,200,500,750,1000];
107    ELITIST=[0,0.05, 0.1, 0.25, 0.5, 0.75, 1] ;
108    STOP_PERCENTAGE=.95;
109    PR_CROSS=[0, 0.05, 0.1, 0.25, 0.5, 0.75, 1];
110    PR_MUT=[1,0.95, 0.9, 0.75, 0.5, 0.25, 0];
111    LOCALLOOP=1;
112    %
113    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
114
115    datasetslist = dir('datasets/');
116    datasets=cell( size(datasetslist,1)-2 ,1);
117
118    upbound = size(NIND);
119    modality = 0;
120
121    if (strcmp(CROSSOVER, 'order-crossover'))
122        modality=1;
123    end
124
125    %possible values for each test, city configurations,# of
126    %different tests
127    values = zeros(upbound(2),size(datasets,1),4);
128
129    for j=1:upbound(2)
130
131        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

```

124
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163

for i=1:size(datasets,1)

    datasets{i} = datasetslist(i+2).name;
    data = load(['datasets/' datasets{i}]);
    x=data(:,1)/max([data(:,1);data(:,2)]);
    y=data(:,2)/max([data(:,1);data(:,2)]);
    NVAR=size(data,1);

    %Tests for number of indv
    temp = zeros(reps,1);
    for n=1:reps
        temp(n)=run_ga_test(modality,x,y,NIND(j),
            MAXGEN(1),...
                NVAR, ELITIST(1), ...
                STOP_PERCENTAGE, PR_CROSS(1),
                PR_MUT(1),...
                CROSSOVER, LOCALLOOP );
    end
    values(j,i,1) = median(temp) ;

    %Tests for number of generations
    temp = zeros(reps,1);
    for n=1:reps
        temp(n)=run_ga_test(modality,x,y,NIND(1), ...
            MAXGEN(j),NVAR, ELITIST(1), ...
            STOP_PERCENTAGE, PR_CROSS(1),
            PR_MUT(1),...
            CROSSOVER, LOCALLOOP );
    end
    values(j,i,2) = median(temp) ;

    %Tests for elitism
    temp = zeros(reps,1);
    for n=1:reps
        temp(n)=run_ga_test(modality,x,y,NIND(1),
            MAXGEN(1), ...
                NVAR, ELITIST(j), ...
                STOP_PERCENTAGE, PR_CROSS(1),
                PR_MUT(1),...
                CROSSOVER, LOCALLOOP );
    end
    values(j,i,3) = median(temp) ;

```

```

164 %Tests for % of crossover and mutation
165 temp = zeros(reps,1);
166 for n=1:reps
167     temp(n)=run_ga_test(modality,x,y,NIND(1),
168                         MAXGEN(1), ...
169                         NVAR, ELITIST(1), ...
170                         STOP_PERCENTAGE, PR_CROSS(j),
171                         PR_MUT(j), ...
172                         CROSSOVER, LOCALLOOP );
173 end
174 values(j,i,4) = median(temp);
175
176 end %for i=1:size(datasets,1);
177 end %for n=1,size(NIND)

178
179 %Plots
180 %Number of indv plot
181 nindF = figure;
182 p = plot(NIND,values(:,:,1));
183 xlabel('#_of_Individuals');
184 title('Increase_of_number_of_individuals_(all_datasets)');
185 ylabel('TSP_distance');
186 set(gca,'XTick',NIND);
187 saveas(nindF, strcat('tests/',CROSSOVER, '/numberIndiv'),
188         'jpg');
189 close(nindF);

190
191 %Number of gen plot
192 genF = figure;
193 p = plot(NIND,values(:,:,2));
194 xlabel('#_of_Generations');
195 title('Increase_of_generations_(all_datasets)');
196 ylabel('TSP_distance');
197 set(gca,'XTick',MAXGEN);
198 saveas(genF, strcat('tests/',CROSSOVER, '/numberGens'),
199         'jpg');
200 close(genF);

201
202 %Elitism plot
203 elitF = figure;
204 p = plot(ELITIST,values(:,:,3));
205 xlabel('%_of_elitism');
206 title('Increase_of_elitism_(all_datasets)');

```

```

205 ylabel( 'TSP_distance' );
206 set(gca, 'XTick', ELITIST);
207 saveas(elitF, strcat('tests/' ,CROSSOVER, '/elitism'), 'jpg');
208 close(elitF);

209
210 %Crossover/mutation plot
211 porcF = figure;
212 p = plot([1:size(PR_CROSS,2)], values(:,:,4));
213 xlabel('%of_Crossover|Mutation');
214 title('Percentage_of_Crossover_and_mutation');
215 ylabel('TSP_distance');
216 xlab = { '0|1', '0.05|0.95', '0.1|0.9', '0.25|0.75', '0.5|0.5' ...
217 '0.75|0.25', '1|0' };
218 set(gca, 'XLim',[1 size(PR_CROSS,2)], 'XTick',1:size(
219 PR_CROSS,2) ...
220 , 'XTickLabel',xlab)
221 saveas(porcF, strcat('tests/' ,CROSSOVER, '/crossMut'), 'jpg');
222 close(porcF);

223 end %if (n==2 || n==3)
224 end %end of function

225
226 function perform_optest()
227
228 %Testing optional
229 datasetslist = dir('datasets/');
230 datasets=cell(size(datasetslist,1)-2,1);
231 for i=1:size(datasets,1)
232 datasets{i} = datasetslist(i+2).name;
233 end
234 data = load(['datasets/' datasets{1}]);
235 x=data(:,1)/max([data(:,1);data(:,2)]);
236 y=data(:,2)/max([data(:,1);data(:,2)]);

237 NVAR=size(data,1);

238 NIND=50; % Number of individuals
239 MAXGEN=50; % Maximum no. of generations
240 SELECTION=[10,15,30,45,50]; % Number of indv to be selected
241 after tournament
242 PR_CROSS=.95; % probability of crossover
243 PR_MUT=.05; % probability of mutation

```

```

245 LOCALLOOP=0;           % local loop removal
246 CROSSOVER = 'order_crossover'; % default crossover operator
247
248 upbound = size(SELECTION);
249 for i=1:upbound(2)
250     tspgui_test(CROSSOVER, NIND, MAXGEN,SELECTION(i), ...
251     PR_CROSS,PR_MUT,LOCALLOOP, ...
252         strcat('tests/optional_ ',num2str(i)) );
253 end
254
255 %val = run_ga_test(1,x,y,NIND, MAXGEN, NVAR, SELECTION,
256 %STOP_PERCENTAGE, ...
257 %PR_CROSS, PR_MUT, CROSSOVER, LOCALLOOP);
258 %display(val);
259 end

```

## 4.12 select\_rr.m

```

1 % Modified SELECT.M, now uses round robin tournament instead of
2 % elitism
3
4 % Syntax: SelCh = select_rr(SEL_F, Chrom, FitnV, GGAP)
5 %
6 % Input parameters:
7 % SEL_F      – Name of the selection function
8 % Chrom       – Matrix containing the individuals (parents) of
9 %                 the current
10 %                population. Each row corresponds to one
11 % individual.
12 % FitnV      – Column vector containing the fitness values of
13 %                 the
14 %                individuals in the population.
15 % GGAP        – (optional) Rate of individuals to be selected
16 %                 if omitted 1.0 is assumed
17 %
18 % Output parameters:
19 % SelCh       – Matrix containing the selected individuals.
20
21
22 function SelCh = select_rr(SEL_F, Chrom, FitnV, mu)
23
24 % Check parameter consistency
25 if nargin < 3, error('Not_enough_input_parameter'); end
26
27 % Identify the population size (Nind)

```

```

23 [NindCh ,~] = size(Chrom) ;
24 [NindF ,VarF] = size(FitnV) ;
25 if NindCh ~= NindF , error('Chrom_and_FitnV_disagree') ; end
26 if VarF ~= 1 , error('FitnV_must_be_a_column_vector') ; end
27
28 Nind = NindCh ;
29
30 if nargin < 4 , mu = 10; end
31
32 if nargin > 3
33     if isempty(mu) , mu = 10;
34         elseif isnan(mu) , mu = 10;
35         elseif length(mu) ~= 1 , error('Mu_must_be_a_scalar') ;
36         elseif (mu < 9) , error('Mu_must_be_a_scalar_bigger_
37             than_9') ;
38     end
39 end
40
41 %Select q random individuals
42 q = zeros(10 ,1) ;
43 temp = zeros(10 ,1) ;
44 for i=1:10
45     ind = randi(size(Chrom,1)) ;
46
47     %Avoid repetition
48     while(any(ind==temp))
49         ind=randi(size(Chrom,1)) ;
50     end
51
52     temp(i) = ind ;
53     q(i) = FitnV(ind) ;
54 end
55
56 %Tournament variable , only index and amount of wins is stored
57 tournament = zeros(size(Chrom,1) ,2) ;
58 %Tournament-> every indv compites against q rivals
59 for i=1:size(Chrom,1)
60     tournament(i ,1) = i ;
61     for j=1:size(q,1)
62         if(FitnV(i) > q(j))
63             tournament(i ,2) = tournament(i ,2) + 1;
64         end
65     end
66 end

```

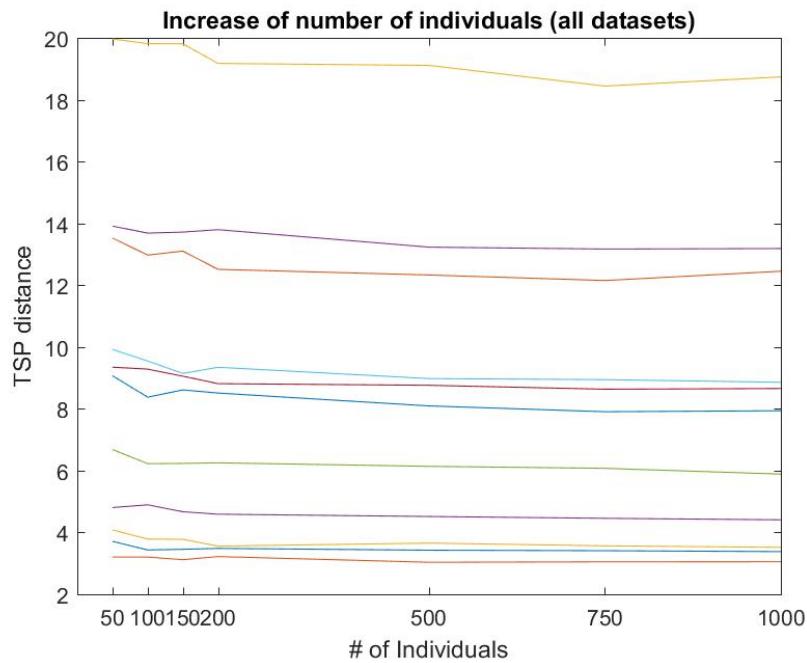
```

67
68 %Sort tournament by amount of wins
69 sortedTournament = sortrows(tournament,2);
70
71 %Indexes of the mu better individuals
72 indexes = sortedTournament(size( ...
73     sortedTournament,1)-mu+1:size(sortedTournament,1),1);
74
75
76 SelCh = [];
77 FitnVSub = FitnV(indexes);
78 ChrIx=feval(SEL_F, FitnVSub, mu);
79 SelCh=[SelCh; Chrom(ChrIx,:)];
80
81 % End of function

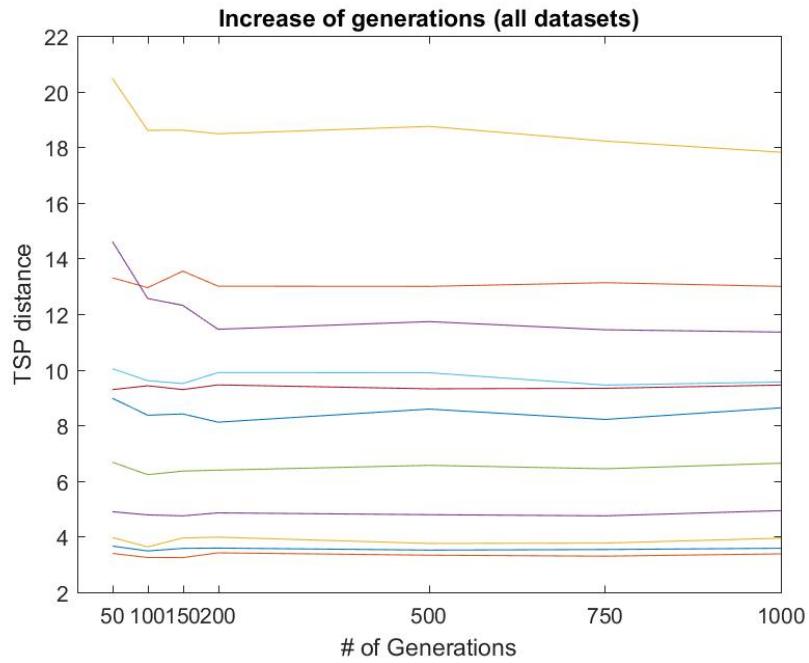
```

## 4.13 Graph

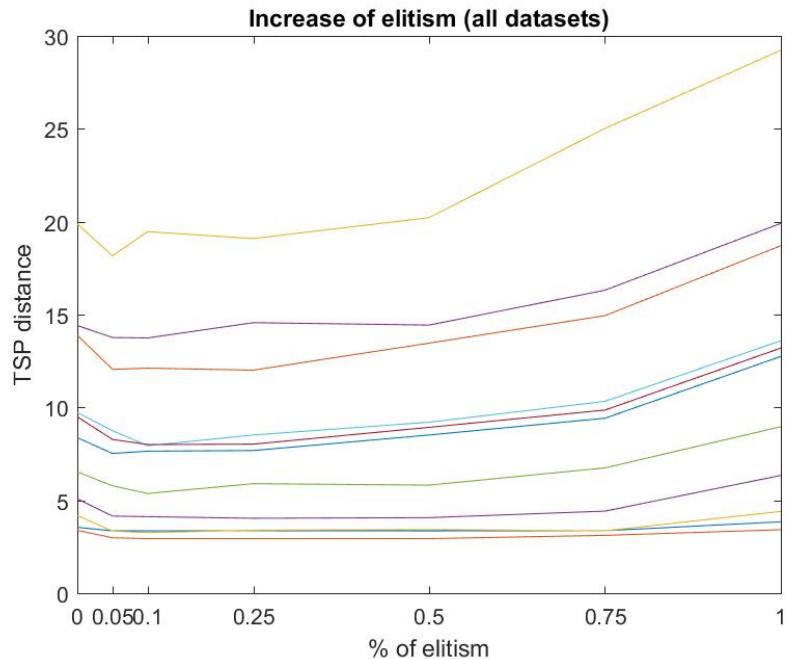
### 4.13.1 Original-General-Individuals



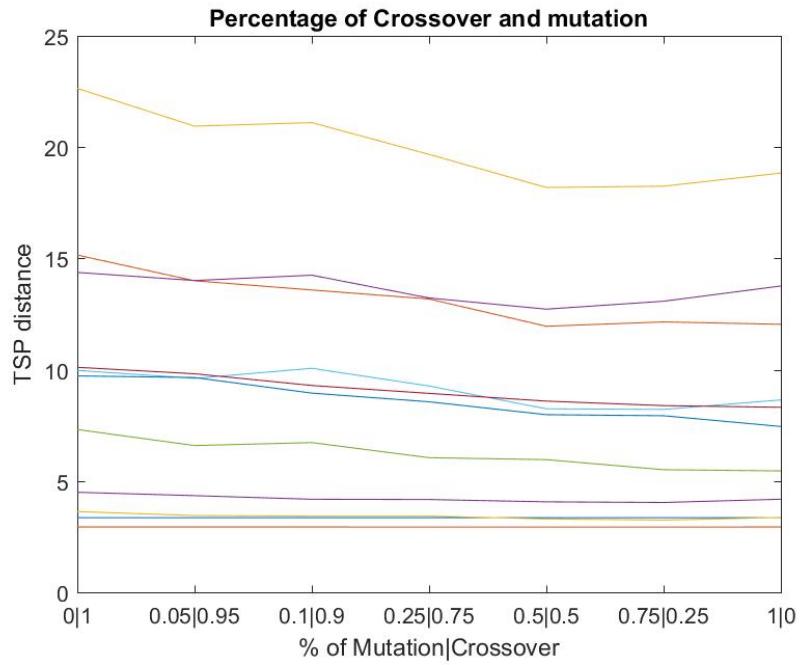
#### 4.13.2 Original-General-Generations



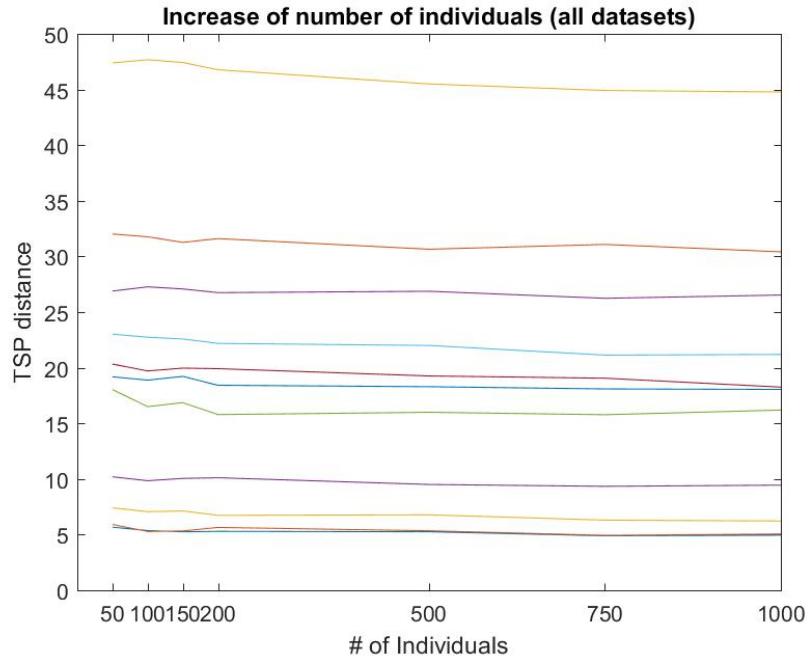
#### 4.13.3 Original-General-Elitism



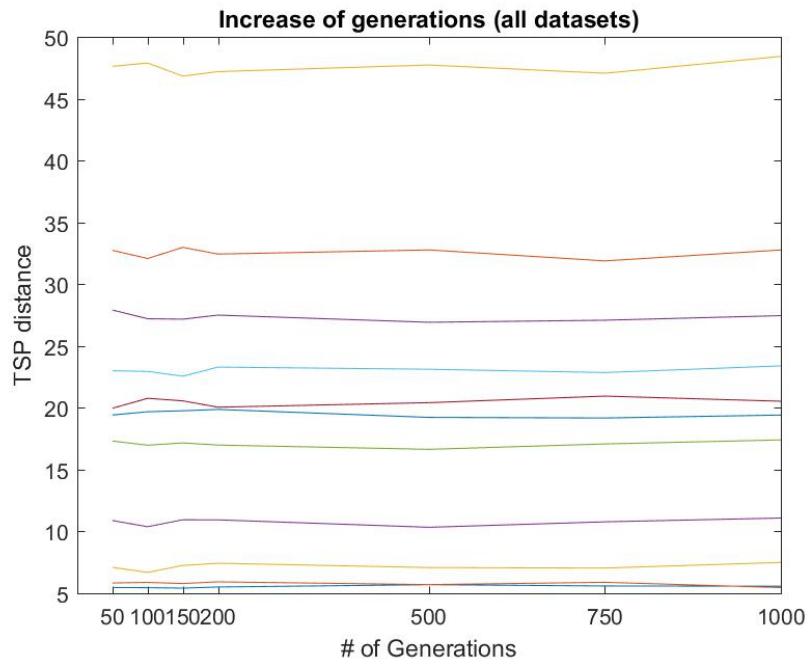
#### 4.13.4 Original-General-Crossover and mutation



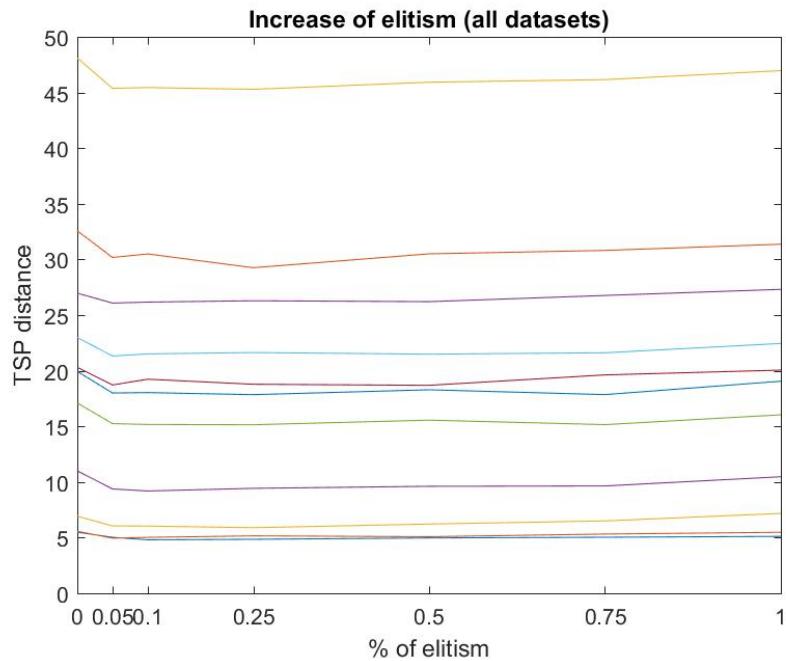
#### 4.13.5 Modified-General-Individuals



#### 4.13.6 Modified-General-Generations



#### 4.13.7 Modified-General-Elitism



#### 4.13.8 Modified-General-Crossover and mutation

