Swarm Intelligence — Implementation Exercise **1**
Ant Colony Optimization

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1. Implement an Ant System algorithm for solving the traveling salesman problem. You can use the template in C++ provided in the files of the course.
   Remember: the tour length is computed starting and ending in the same city.

2. A small set of scripts to analyze your results is provided in files of the course, for using them you must produce an output with the following characteristics:

   (a) Boxplots: Data matrix, ":" separator field, first row is the header containing the names of the columns. First column are the different trial/instances. The rest of the matrix are the values to be plot.

   (b) Wilcoxon test: The same format as above, it provides the p-values of each test pair and performs a Bonferroni correction for multiple comparisons.

   (c) Convergence: Files having the best solution each iteration or tour using the format per line: [tour:tour_length] or [iteration:tour_length]. One file per test.

   Feel free to use these scripts and adapt them to your needs.

3. Define default parameters that you consider adequate for your algorithm ($number\_ants$, α, β and ρ).

4. The following experiments will help you to understand the behavior of AS and to find parameters that are good for the algorithm. Using your implementation of AS execute these experiments:

   (a) Use instances ulysses22.tsp and att532.tsp, execute your algorithm 20 times using 2, 5, 10, 20, 50 and 100 ants. Termination condition: 500 tours.

   (b) Plot the results using boxplots. What behavior can you observe?

   (c) Use instances ulysses22.tsp and att532.tsp, execute your algorithm 20 times using $\{\alpha = 1,\ \beta = 0\}$ and $\{\alpha = 0,\ \beta = 1\}$. Termination condition: 500 tours.

   (d) What behavior can you observe? Is the convergence different?

   (e) Use instance ulysses22.tsp and att532.tsp, execute your algorithm 20 times using $\{\alpha = 1,\ \beta = 1,\ \rho = 0.01\}$ and $\{\alpha = 1,\ \beta = 1,\ \rho = 0.5\}$,

$\{\alpha = 1,\ \beta = 1,\ \rho = 0.7\}$, $\{\alpha = 1,\ \beta = 1,\ \rho = 1\}$. Termination condition: 500 tours.

(f) Plot the results using boxplots. What behavior can you observe?

5. For next class: Think about ways to improve the Ant System you have implemented today. You can propose changes in the way the pheromone is updated and evaporated, how to apply the transition rule, heuristics...