# Project 2 Heuristic Optimization: ACO for TSP

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**Introduction**

In this work we present the measured runtimes of our Ant Colony Optimization implementation in Python 3.4, run with pypy3, on symmetric traveling salesperson (TSP) problem instances of 17 and 26 cities respectively (gr17 and fri26).
We executed our program on a MacBook Air with 1.8 GHz Intel Core i5 with 4 logical cores (two cores with hyperthreading) and 8GB RAM, running OSX 10.9.5.
In the following we discuss the runtime of the algorithm while variating the problem size and the parameters ? , , and . For each parameter set we ran the algorithm 10 times and therefore present 10 curves as well as a curve representing the average of the 10 individual curves, computed by the mean of all values in 10 equally sized ranges of the horizontal axis (marked in axis on top).

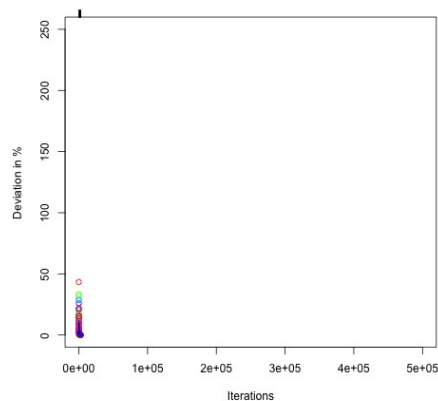**Favoring heuristic information over pheromone values**

**Rho=0.1**

**Fri26**
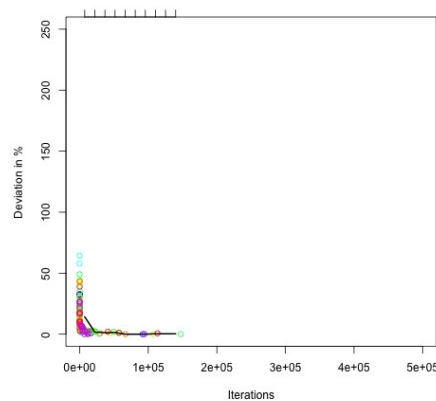


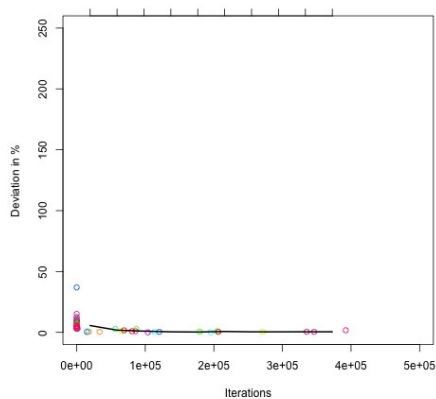Figure 1: alpha=0.1, beta=8    Figure 2: alpha=1, beta=8
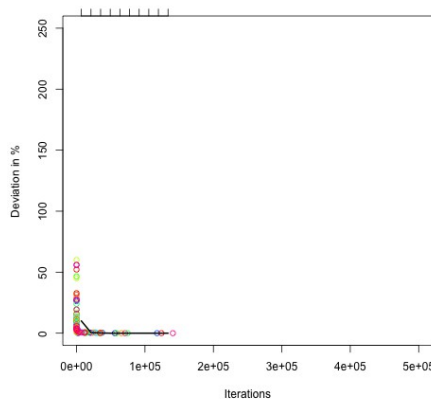
**gr17**



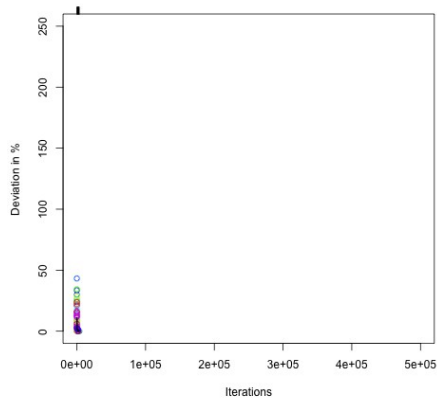Figure 4: alpha=0.1, beta=8    Figure 3: alpha=1, beta=4

**Rho=0.5**

**fri26**



Figure 5: alpha=0.1, beta=8
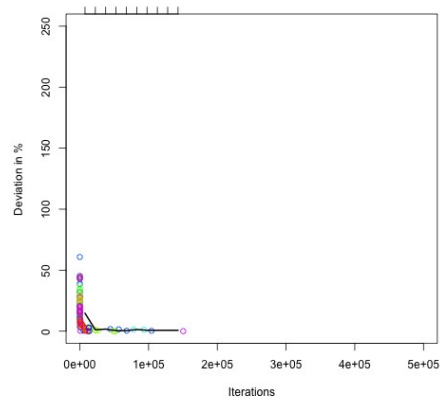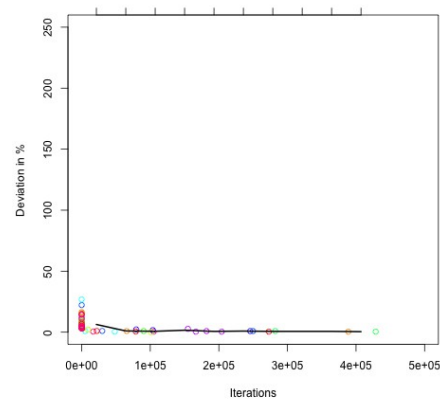


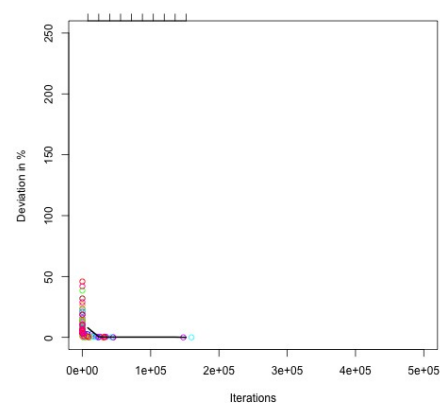Figure 6: alpha=1, beta=4

**gr17**



Figure 8: alpha=0.1, beta=8



Figure 7: alpha=1, beta=4

**Rho=0.8**

**fri26**



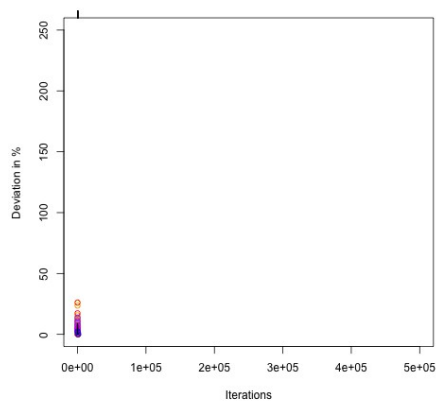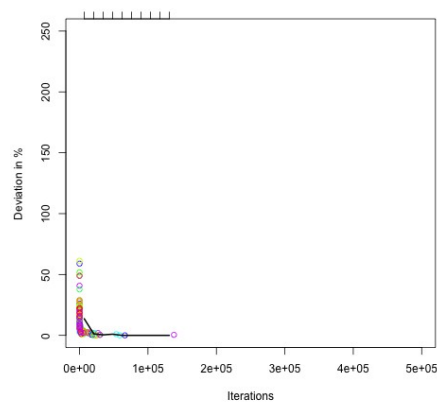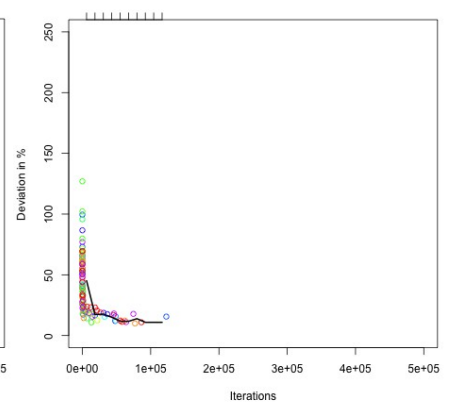*Figure 9: alpha=0.1, beta=8*



*Figure 10: alpha=1, beta=4*



*Figure 11: alpha=1, beta=2*

**gr17**



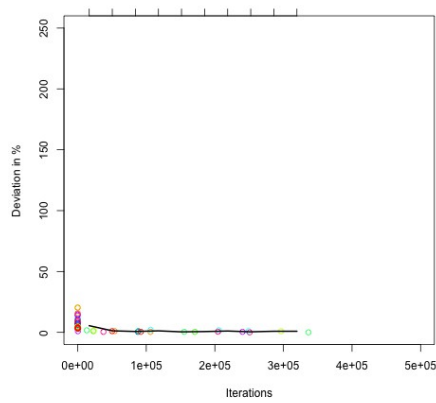*Figure 12: alpha=0.1, beta=8*



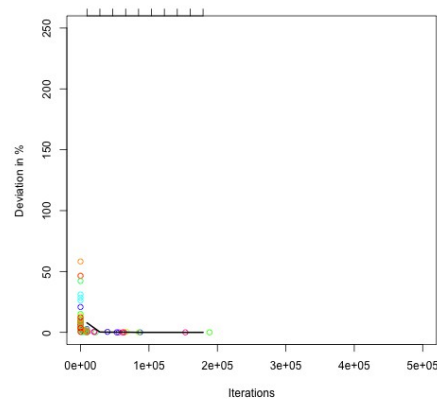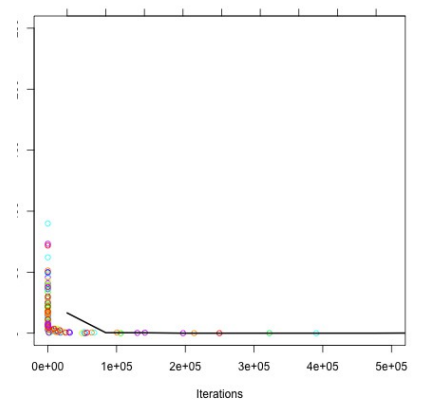*Figure 13: alpha=1, beta=4*



*Figure 14: alpha=1, beta=2*

**Equally weighting pheromones and heuristic information**
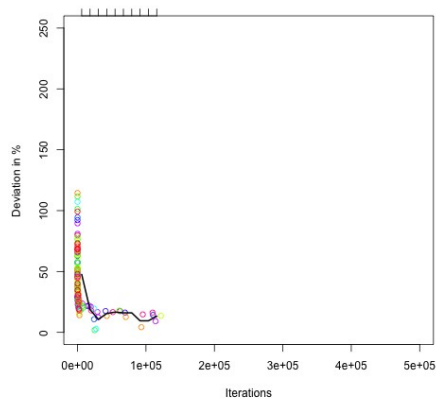
**fri26**



Figure 15: alpha=2, beta=2, rho=0.1
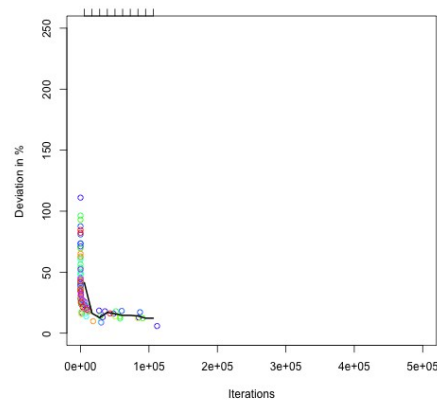


Figure 16: alpha=2, beta=2, rho=0.5



Figure 17: alpha=2, beta=2, rho=0.8

**gr17**



Figure 18: alpha=2, beta=2, rho=0.1



Figure 19: alpha=2, beta=2, rho=0.5
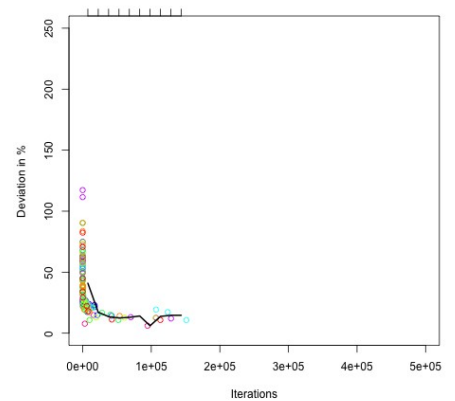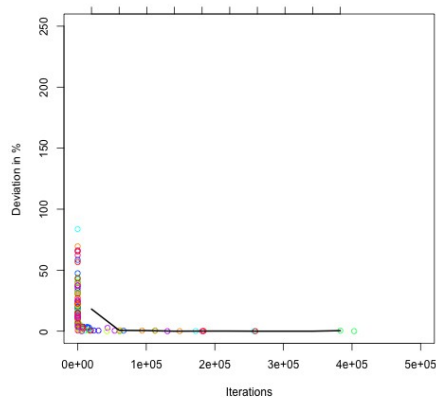


Figure 20: alpha=2, beta=2, rho=0.8

**Favoring pheromone values over heuristic information**

**fri26**



*Figure 23: alpha=3, beta=0, rho=0.1*



*Figure 21: alpha=3, beta=0, rho=0.5*



*Figure 22: alpha=3, beta=0, rho=0.8*

**gr17**



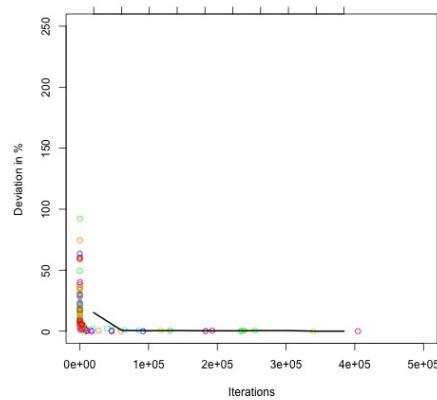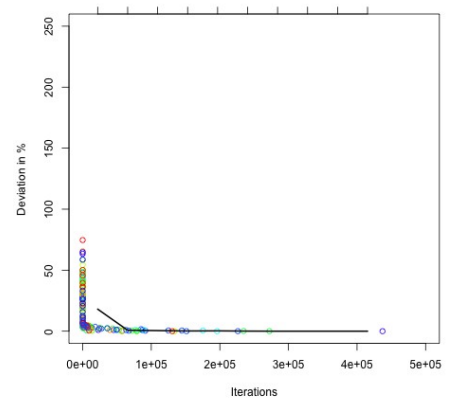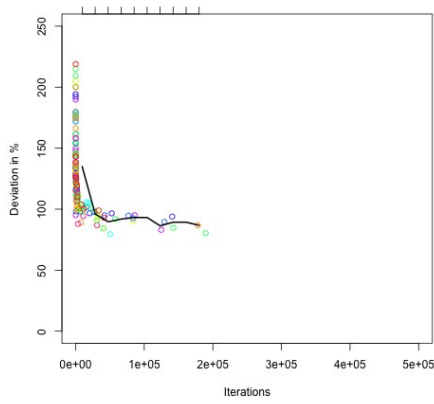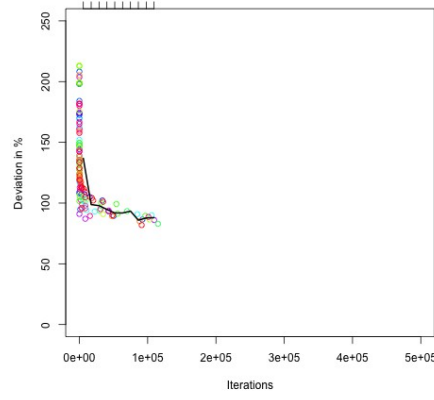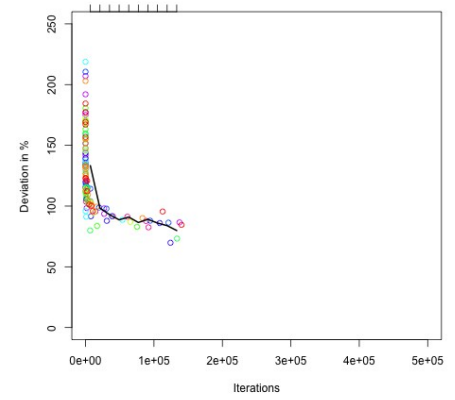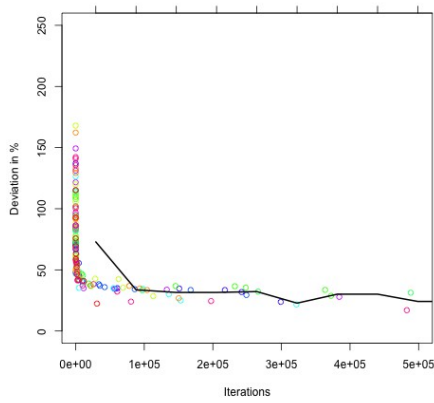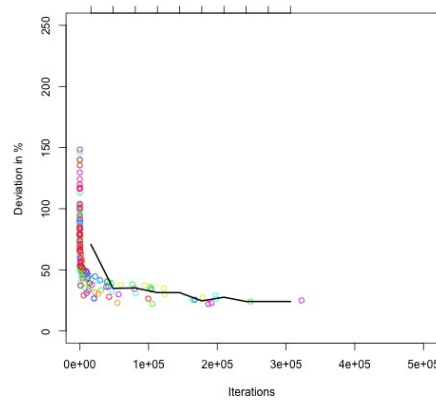*Figure 24: alpha=3, beta=0, rho=0.1*
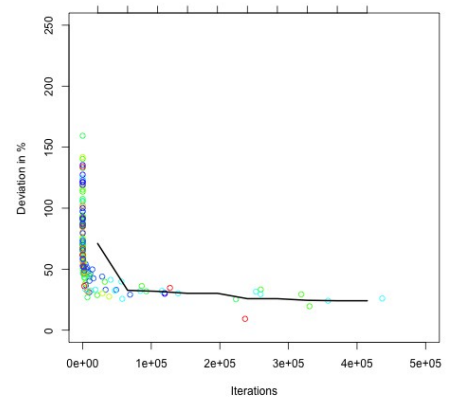


*Figure 25: alpha=3, beta=0, rho=0.5*



*Figure 26: alpha=3, beta=0, rho=0.8*

**Discussion of Effect of Parameters and Problem Size**

*Favoring pheromones over heuristic information leads to poorly optimal solutions*
It is notable that the initial solutions are the worst of all parameter settings, especially for larger problems. For the problem *fri26*, the intial solutions lie up to 230% above the optimal solution and average around 140% above the optimum in the first 1400 iterations (see Figure 21-23). But even after 10 minutes no run succeeded to find a solution at most 60% above the optimum.
The same effects can be observed for the smaller problem gr17 but on a different scale: the average of the best found solutions lie around 30% above the optimum with outliers ranging within 10% (see Figure 24-26).

*Strongly weighting heuristic information leads to fastest convergence*
It can be observed that the higher the ratio between alpha and beta, the quicker converges the algorithm to the optimal solution. In the Figures 1-14 can be seen that beta=8 and alpha=0.1 converges more quickly than beta=2 and alpha=1). This holds true independently of the value of rho as can be seen by comparing Figures with the same alpha and beta for the same problem but with varying rho as can be seen e.g. in the Figures 1, 5, and 8 or the Figures 2, 6, and 10 respectively. Although a greater rho slows the convergence process down, the general trend of higher ratio meaning faster convergence is not changed.
However, the problem size has an interesting effect: In Figure 11 it is visible, that for the larger problem *fri26* the algorithm is no longer able to find a nearly optimal solution. There was no run out of 10, which found a solution at most 15% more costly than the optimum.

*Equally weighting heuristic information and pheromones leads to slower convergence for larger rho*
In Figure 15-20, especially Figure 15-17 as they show the harder problem *fri26*, is is visible that the temporarily best-known solution of the algorithms converges slower to the optimum as rho increases. This might be due to the fact that poor routes which have been chosen are more likely to be chosen again as the pheromones evaporate less  quickly for greater rho. These poor routes are also more likely to be chosen in comparison to other scenarios, because the heuristic information of the edge length is considered too little important in this parameter setting.

*Smaller problem gr17 almost always converges more slowly than fri26*
Another observation is that the smaller problem *gr17* seems to converge more slowly than the larger one *fri26* as is indicated by comparing the Figures 1 and 4,  5, 8, as well as 9 and 12. This effect even continues for equal alpha and beta, both set to 2, and for a larger alpha than beta.

*Smaller problem gr17 continue to improve slightly over longer time thsn fri26*
However, it should be noted that the solutions for the smaller problem are usually more optimal after less iterations and continue to improve slightly over a longer timespan, whereas for the larger problems the algorithms is not able to improve found solutions after less iterations. This effect is nearly always visible when comparing the Figures in the first (*fri26)* and second lines (*gr17)* of a section. When halting the search after having found a solution, let's say, no worse than at most 10% above the optimum, this effect would only still be observable in Figures 21-26, where alpha is higher than beta and the solutions are poor even for the small problem *gr17*.