Pheromone Modification Strategies for Ant Algorithms applied to Dynamic TSP

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Problem

Traveling Salesperson Problem

Solution has been found

Cities are added or removed

Considerations

Could restart ants after change

Could account for previous pheromone matrix

Ant System Overview

Probability distribution over set of cities S determined by:

$$p_{ij} = \frac{[\tau_{ij}]^\alpha [\eta_{ij}]^\beta}{\sum_{h \in S} [\tau_{ih}]^\alpha [\eta_{ih}]^\beta}$$

Initial Pheromones:

$$\tau_{ij} = 1/(n-1)$$

Pheromone Evaporation:

$$\tau_{ij} \mapsto (1-\rho) \cdot \tau_{ij}$$

Pheromone Update:

$$\tau_{ij} \mapsto \tau_{ij} + \frac{1}{4}\rho$$

Pheromone Modification Strategies

Restart-Strategy
   reinitializes all pheromone values by same degree
η-Strategy
   equalizes pheromone values according to distance between cities
τ-Strategy
   equalizes pheromone values according to pheromone distances

Equalization

Strategies distribute reset value $\gamma_i \in [0{:}1]$ to each city i

Reset-values used to reinitialize pheromone values on edges incident to city i according to:

$$\tau_{ij} \mapsto (1 - \gamma_i)\tau_{ij} + \gamma_i \frac{1}{n-1}$$

Restart

Assigns each city i the reset value
$\lambda_R \in [0{:}1]$

$$\gamma_i = \lambda_R.$$

η-Strategy

γ_i proportionate to city i's distance from inserted/deleted city j

$$d_{ij}^{\eta} = 1 - \frac{\eta_{avg}}{\lambda_E \cdot \eta_{ij}}$$ $\lambda_E \in [0,\infty)$

Average distance:

$$\eta_{avg} = \frac{1}{n(n-1)} \sum_{i=1}^{n} \sum_{k \neq i} \eta_{ik}$$

Equalization:

$$\gamma_i = \max(0, d_{ij}^{\eta}).$$

τ-Strategy

Pheromone distance between two cities is the maximum over all paths P_{ik} from i to k of the product of pheromone values on the edges in P_{ik}

$$d_{ik}^{\tau} = \max_{P_{ik}} \prod_{(x,y) \in P_{ik}} \frac{\tau_{xy}}{\tau_{max}}.$$

Equalization:

$$\gamma_i = min(1, \lambda_T \cdot d_{ij}^{\tau})$$

$$\lambda_T \in [0, \infty)$$

Visualization-η

Distribution of reset values

Visualization of ETA-Strategy

0.8
0.6
0.4
0.2

(a) η-Strategy, $\lambda_E = 1$

Visualization-т

(b) τ-Strategy, $\lambda_T = 1$
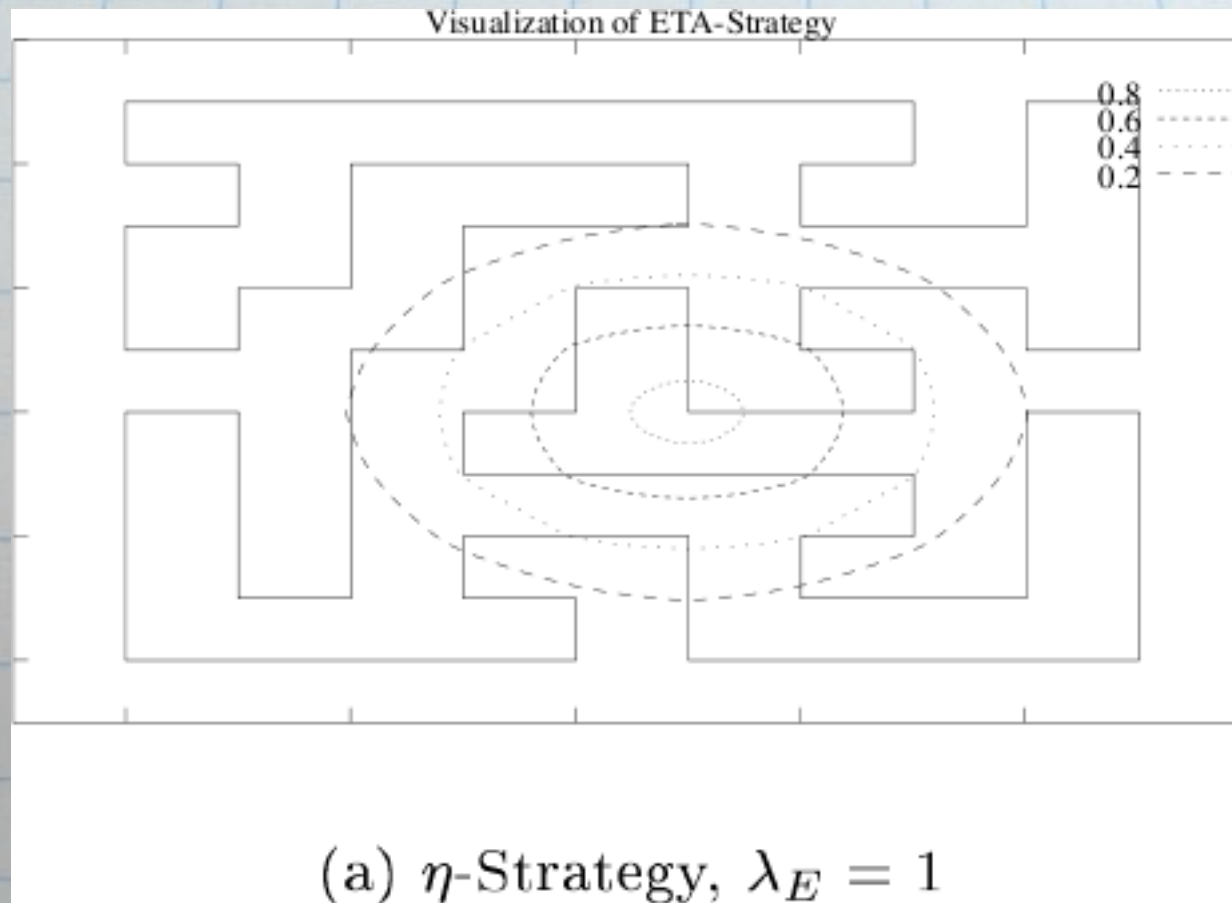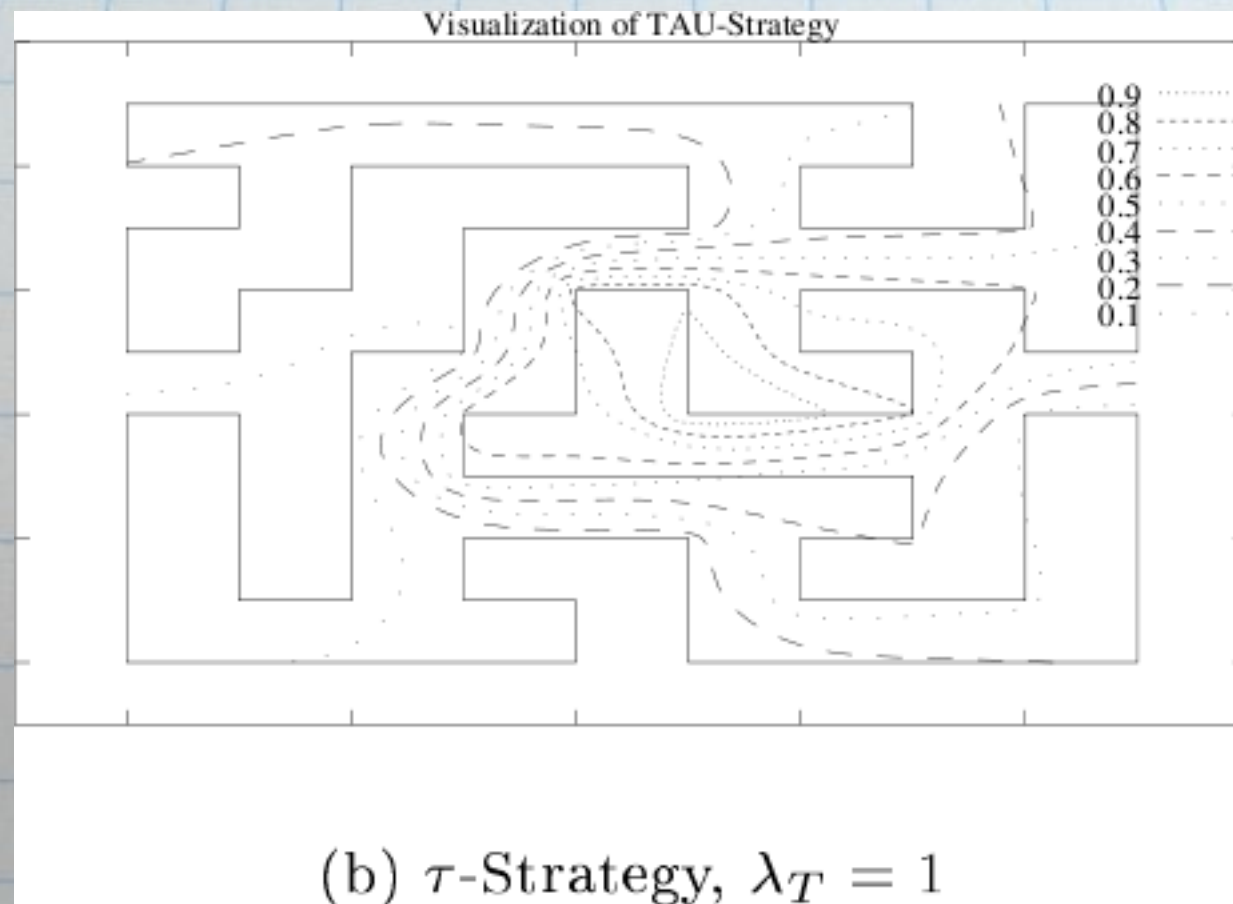
Evaluation

Insertion/deletion was evaluated after 250 and 500 iterations

All test results were averaged over the insertion/deletion of all 101 cities.

Parameters:
m = 10, α=1, β=5, q_0=0.5, ρ=0.01

Entropy

Measured average row-/column-entropy:

$$E = \frac{1}{n \log n} \sum_{i=1}^{n} \sum_{j=1}^{n} -\tau_{ij} \log(\tau_{ij})$$

To obtain an understanding of the total amount of equalization in the pheromone matrix
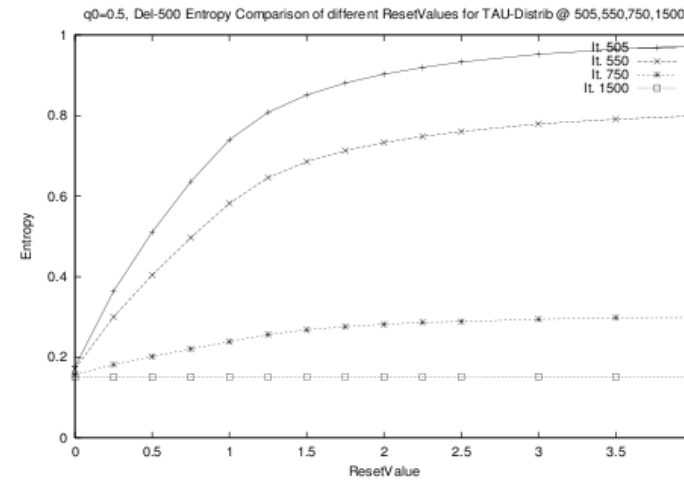
Results η-Strategy
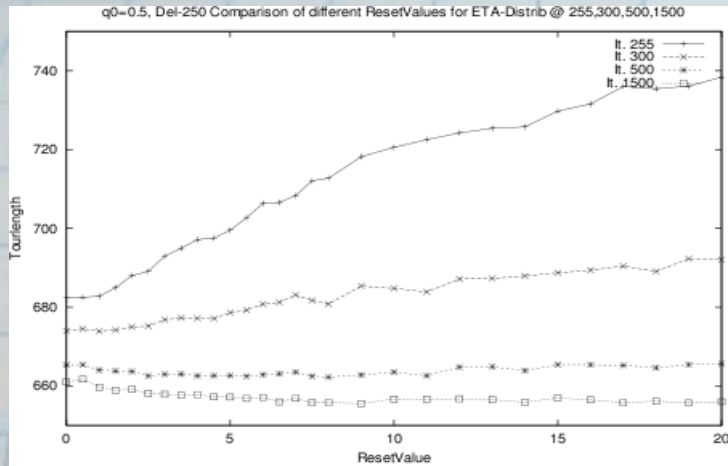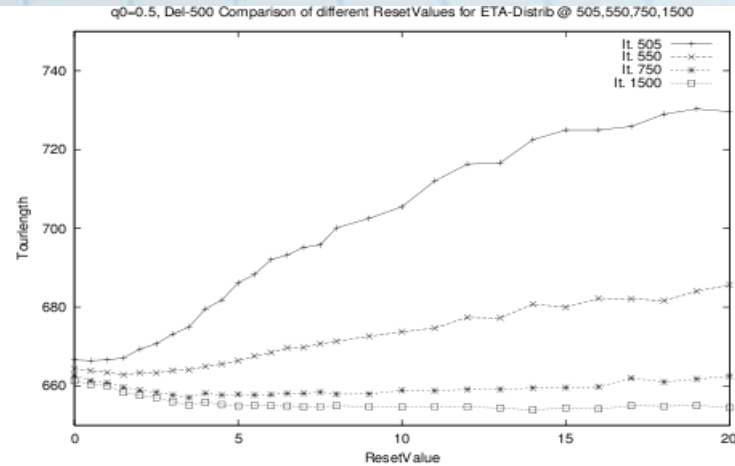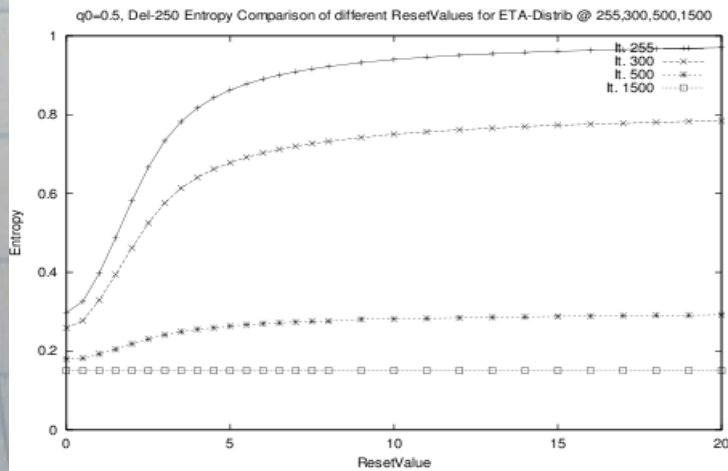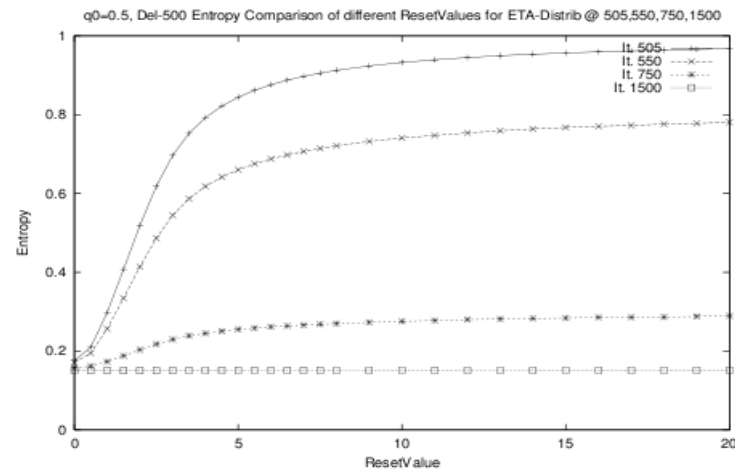
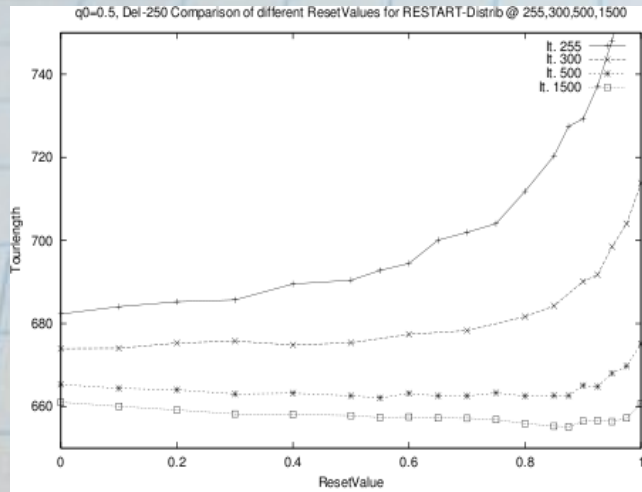(a) del250, best solution

(b) del500, best solution

(c) del250, entropy

(d) del500, entropy
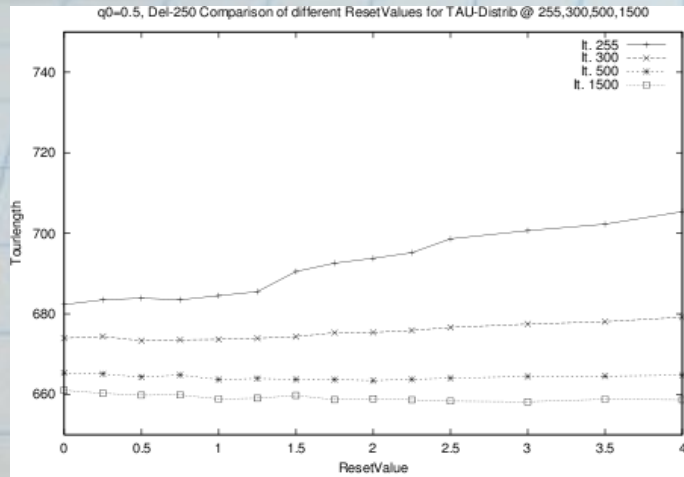
Results τ-Strategy

(a) del250, best solution
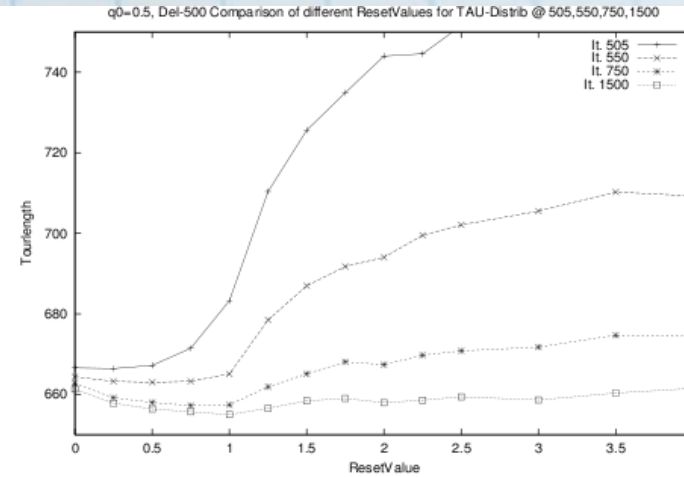
(b) del500, best solution
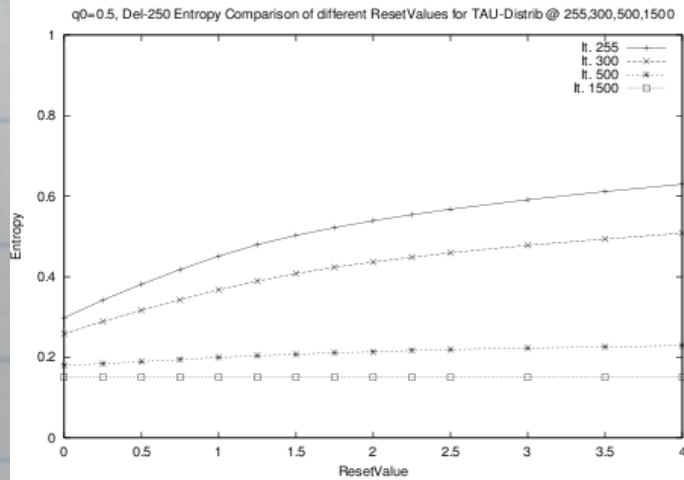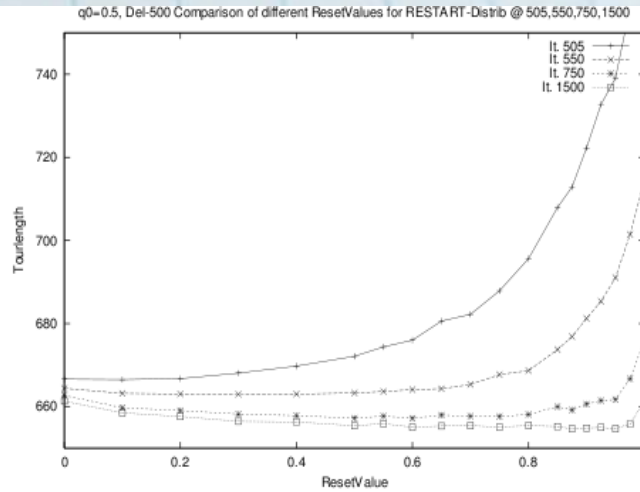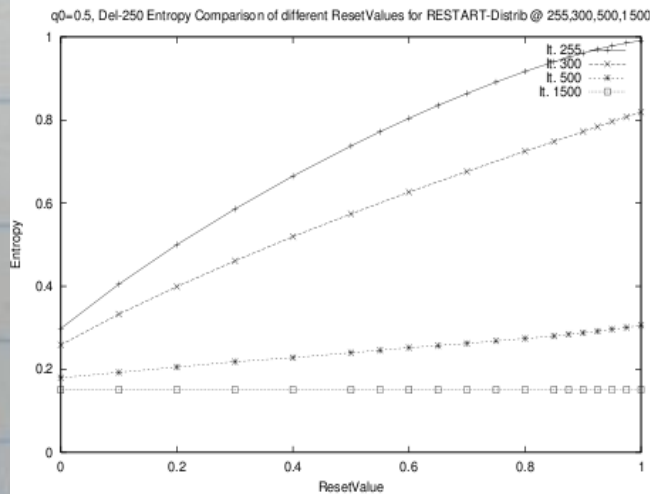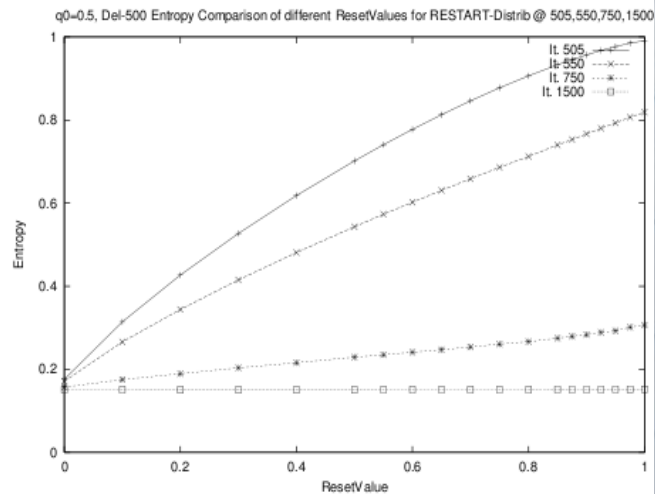
(c) del250, entropy

(d) del500, entropy

Results Restart

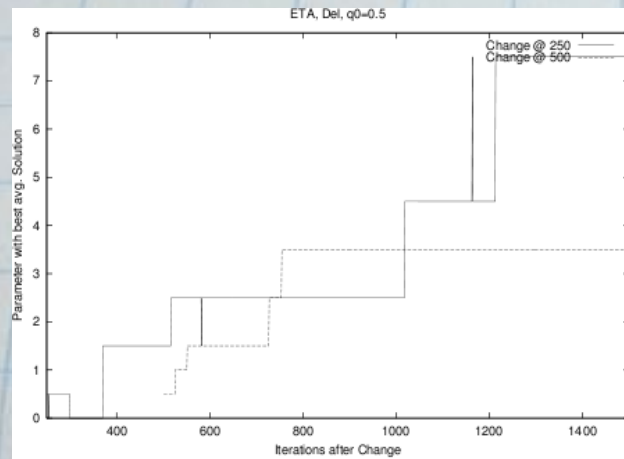(a) del250, best solution

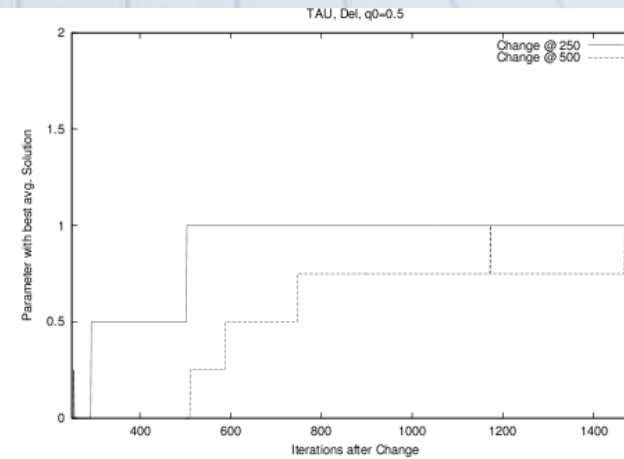(b) del500, best solution

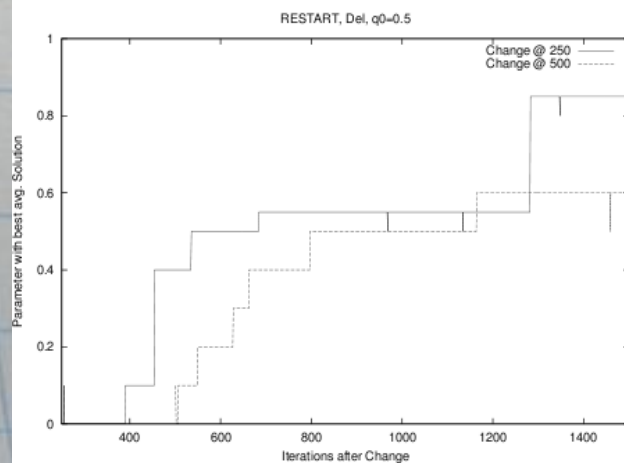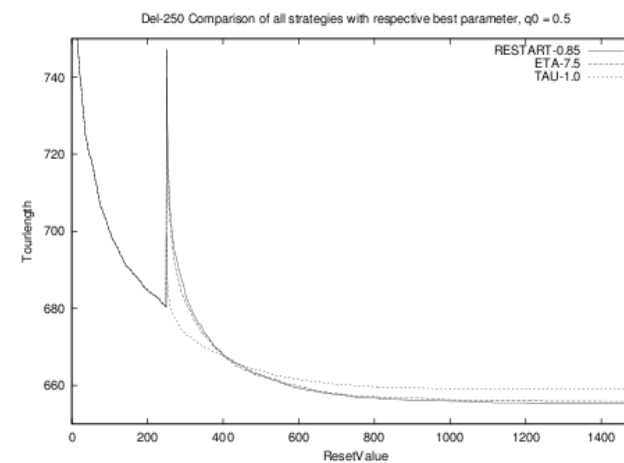(c) del250, entropy

(d) del500, entropy

Final Results

(a) η-Strategy

(b) τ-Strategy

(c) Restart-Strategy

(d) "best" parameters

Conclusion

η-Strategy and Restart perform best

Performance of Restart probably due to the singular delete/insert