HOCHSCHULE
HANNOVER
UNIVERSITY OF
APPLIED SCIENCES
AND ARTS
–
Fakultät IV
Wirtschaft und
Informatik

Improvements on AFB

Advancing the Metaheuristic for TSP

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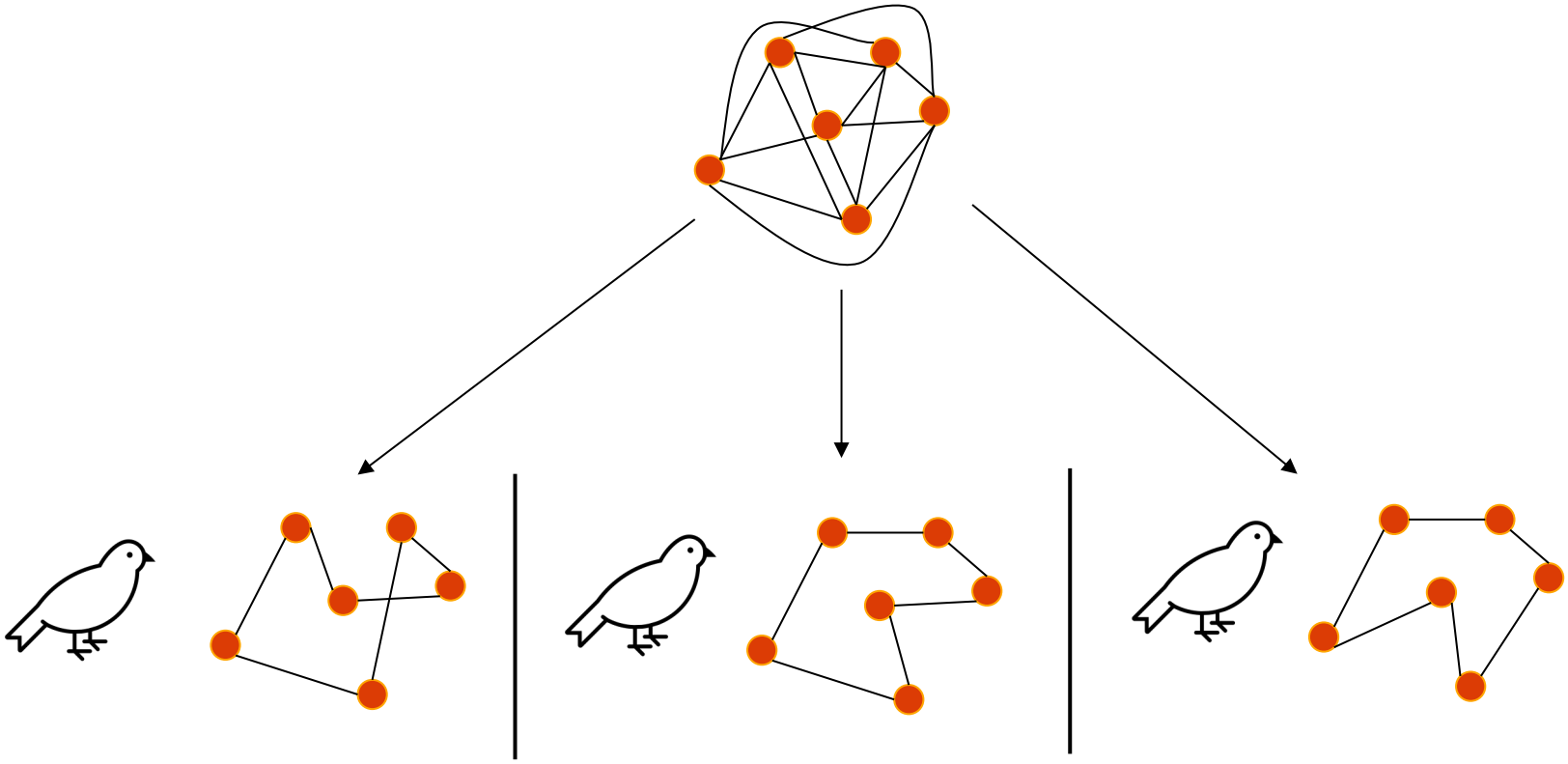
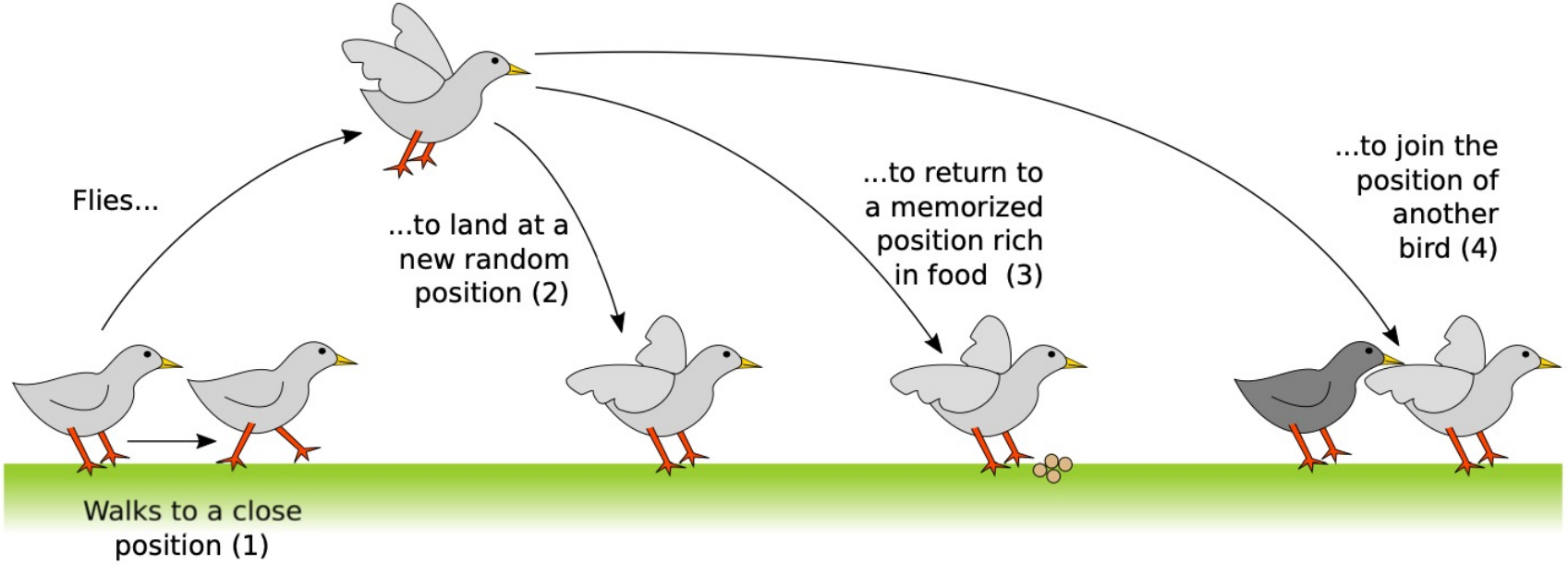
Recap

- Each Birds represents one possible solution (one tour)
- Each operation performed by a bird, alters its respective solutions



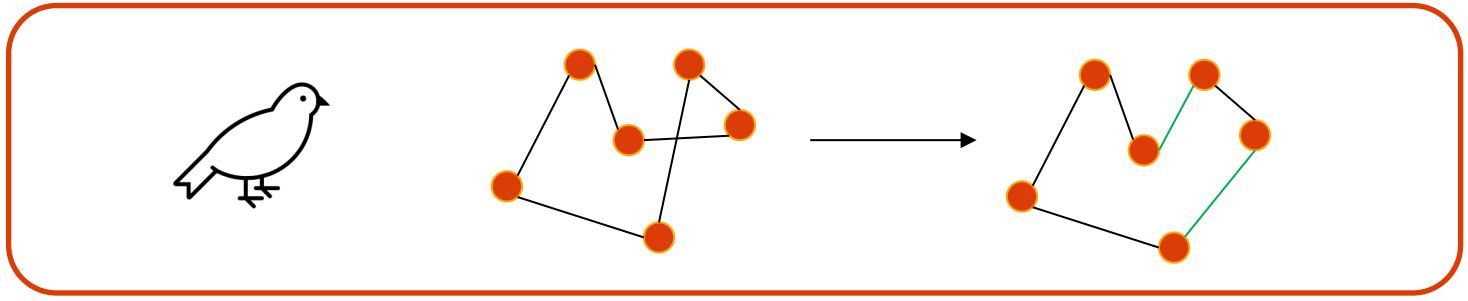
Recap


Flies...
...to land at a new random position (2)
...to return to a memorized position rich in food (3)
...to join the position of another bird (4)
Walks to a close position (1)

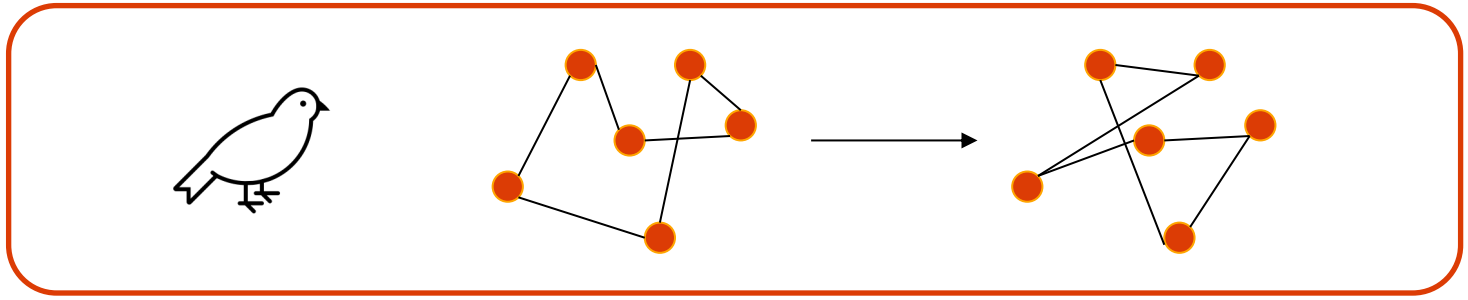
Recap

- Each action of a bird corresponds to a change of its own solution
- Each solution is valid
- The number of candidate solutions (or agents respectively) does not change (currently)

(1) Walk

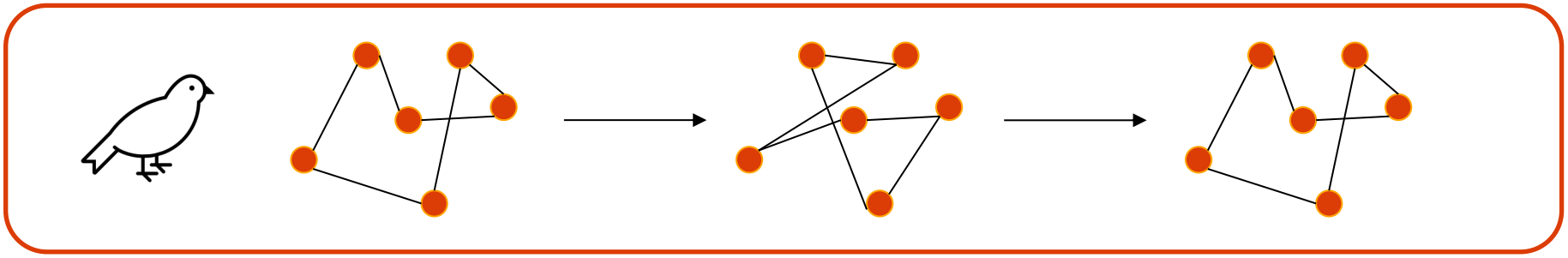


(2) Fly

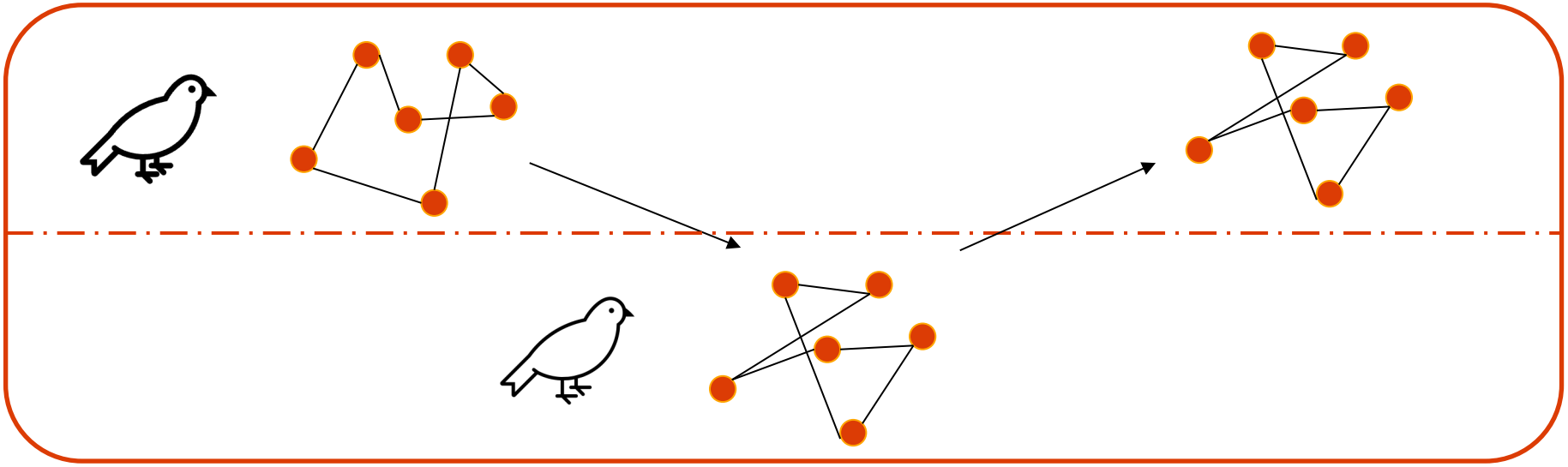


Recap

(3) Return



(4) Join



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Methodology

- To benchmark our improvements, we select five feasible solutions from TSPLIB
  - Each problem has a different order of magnitude to account for the variety of different configurations possible
- Each problem is run 10x, to account for the randomness (50 test in total)
- We record the mean percentage error, and the mean time in seconds
- Problems: eil101, pa561, pr1002, u2156, pr2392

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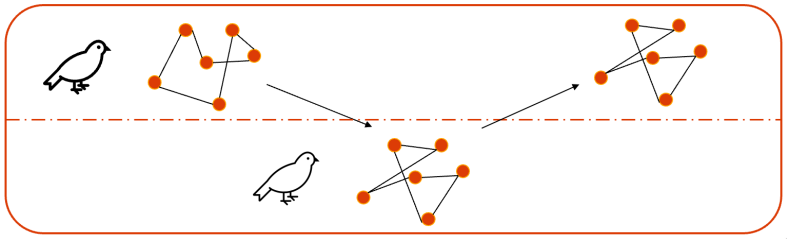
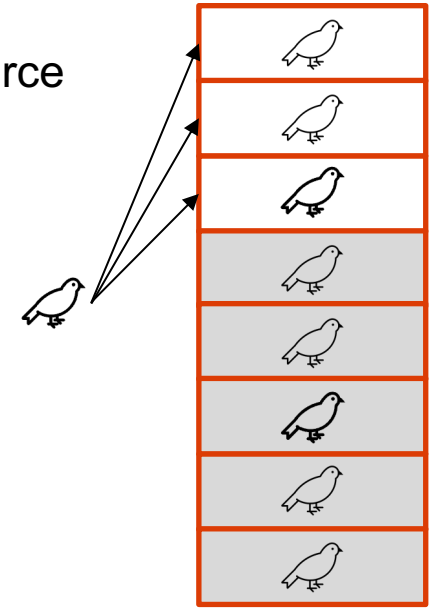
Top-b Join



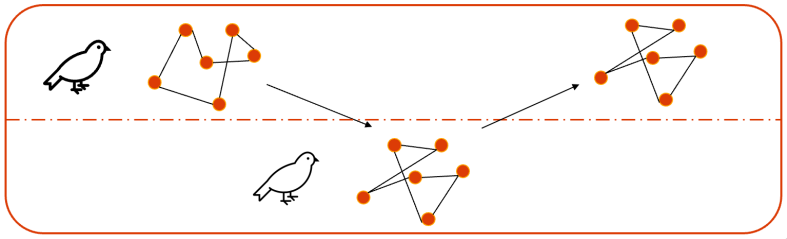
- Default behavior: If a big bird joins another, he chooses one randomly
- Contradicts the idea that birds tend to join others, if they found a good food source
  - Good food source translates to a good solution

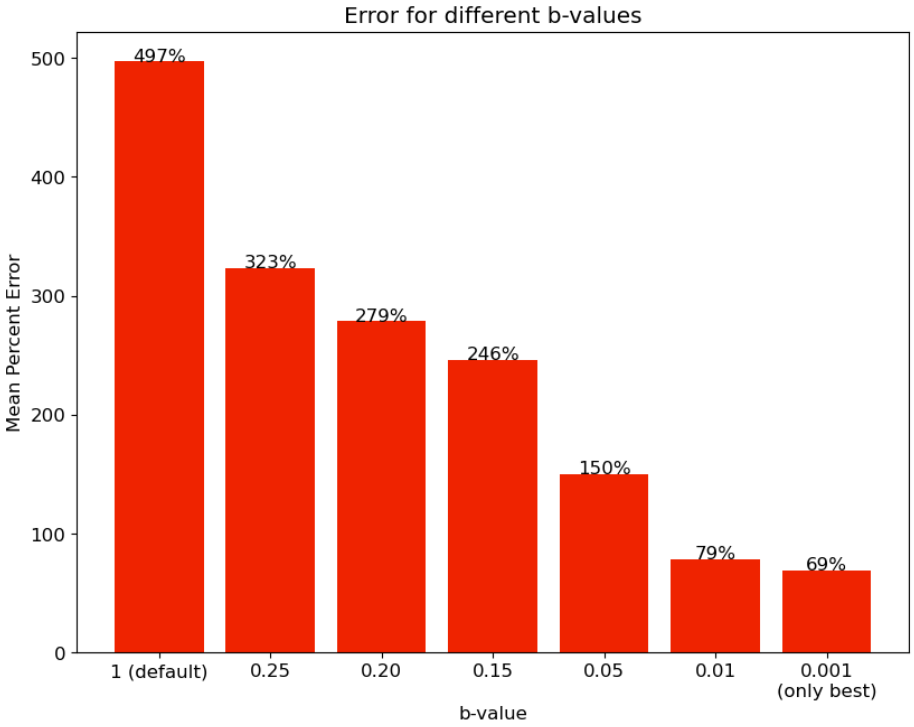


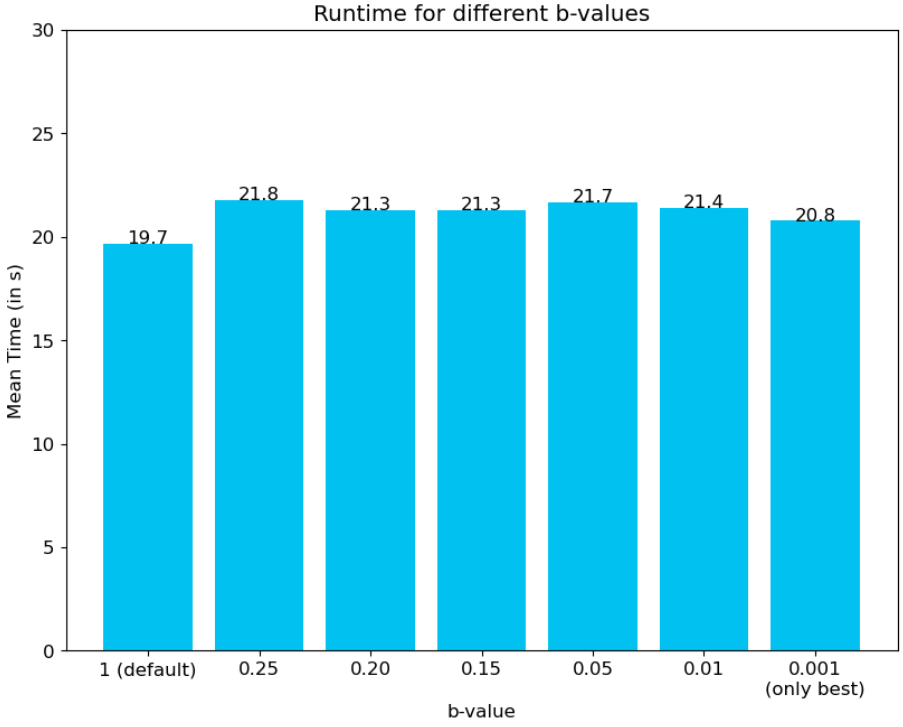
- That is why we decide to allow a big bird to only join the top-b percent
  - Pick one of the top-b birds randomly

- Means ordering the birds by their tour length after each iteration/phase
  - Increases runtime due to sorting complexity

Top-b Join




Error for different b-values
Mean Percent Error
0
100
200
300
400
500
497%
323%
279%
246%
150%
79%
69%
1 (default)
0.25
0.20
0.15
0.05
0.01
0.001
(only best)
b-value


Runtime for different b-values
Mean Time (in s)
0
5
10
15
20
25
30
19.7
21.8
21.3
21.3
21.7
21.4
20.8
1 (default)
0.25
0.20
0.15
0.05
0.01
0.001
(only best)
b-value

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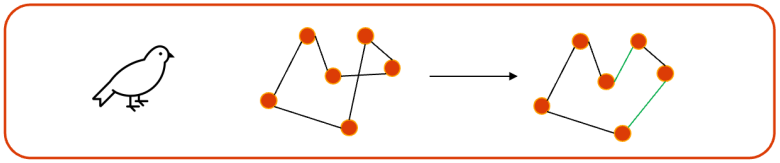
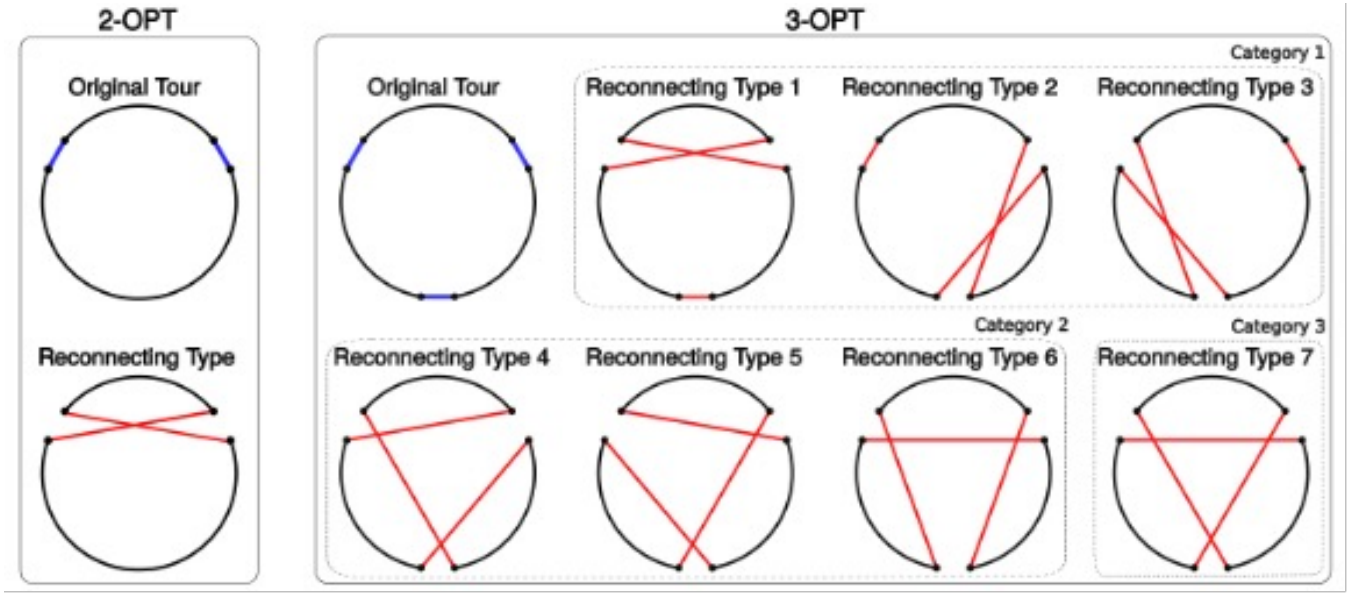
3-Opt

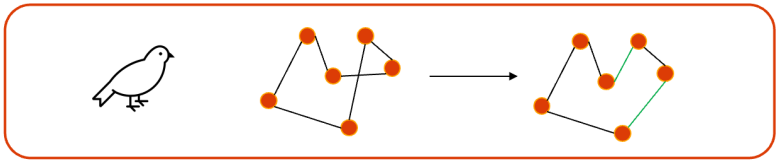


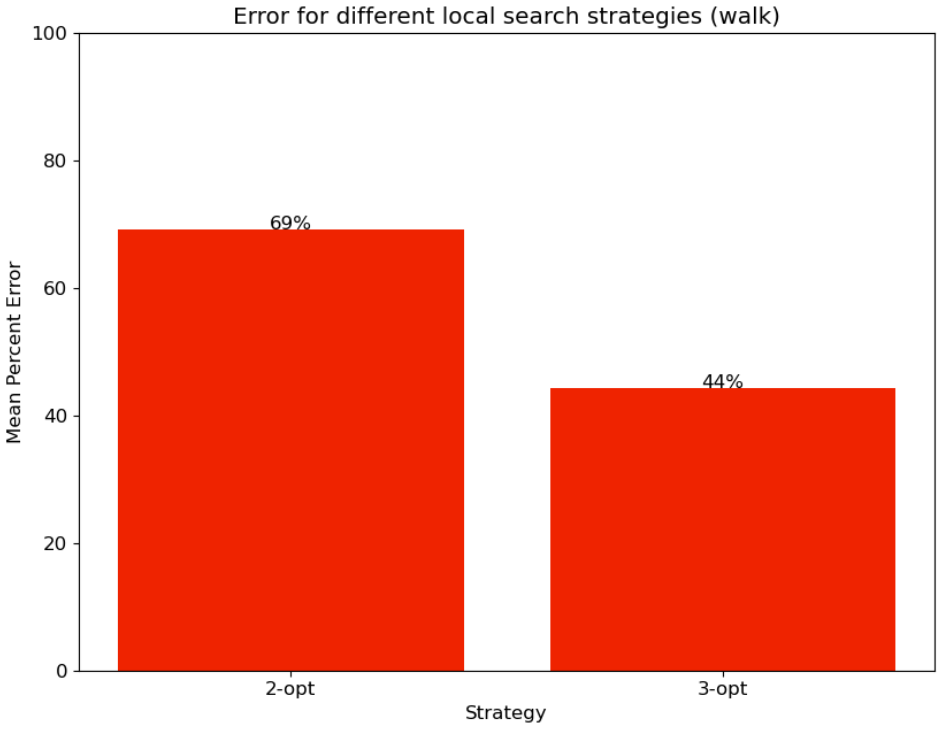
- When performing the walk-operation, so the local search, a bird uses 2-opt to search for a potential better solution
- Naturally, we also tested 3-opt as a more powerful alternative

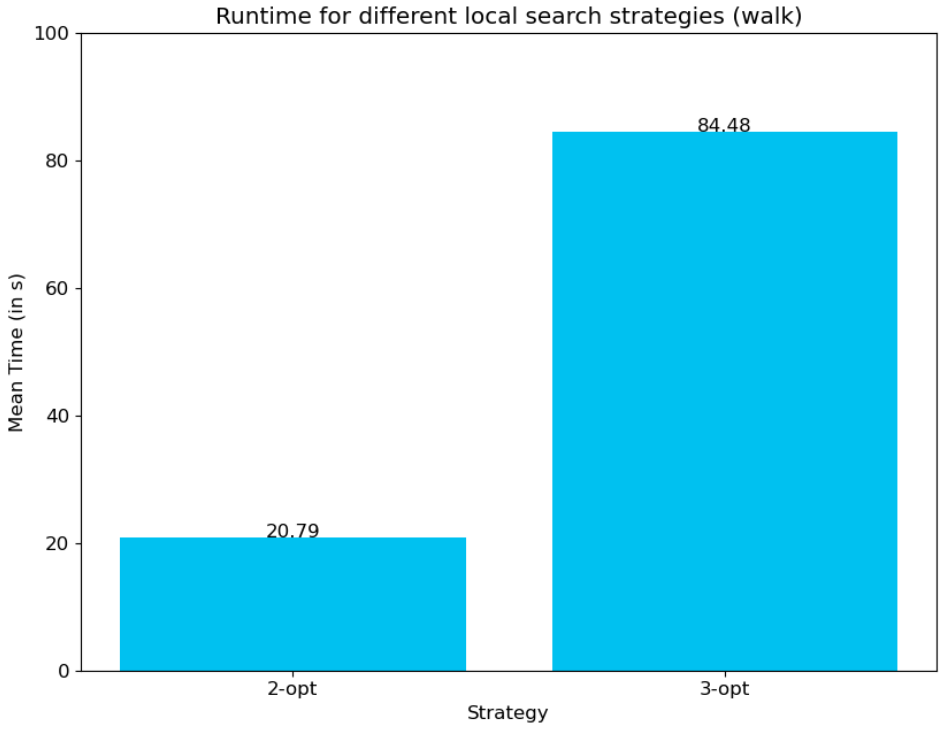


Source: Jingyan Sui, Shizhe Ding, Ruizhi Liu, Liming Xu, Dongbo Bu. Learning 3-opt heuristics for traveling salesman problem via deep reinforcement learning. Proceedings of The 13th Asian Conference on Machine Learning, PMLR 157:1301-1316, 2021.

3-Opt




Error for different local search strategies (walk)
Mean Percent Error
100
80
60
40
20
0
69%
44%
2-opt
3-opt
Strategy


Runtime for different local search strategies (walk)
Mean Time (in s)
100
80
60
40
20
0
20.79
84.48
2-opt
3-opt
Strategy

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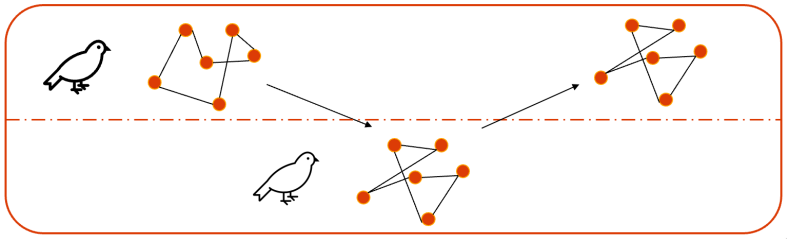
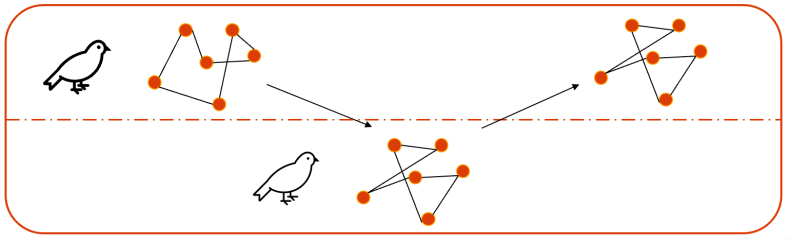
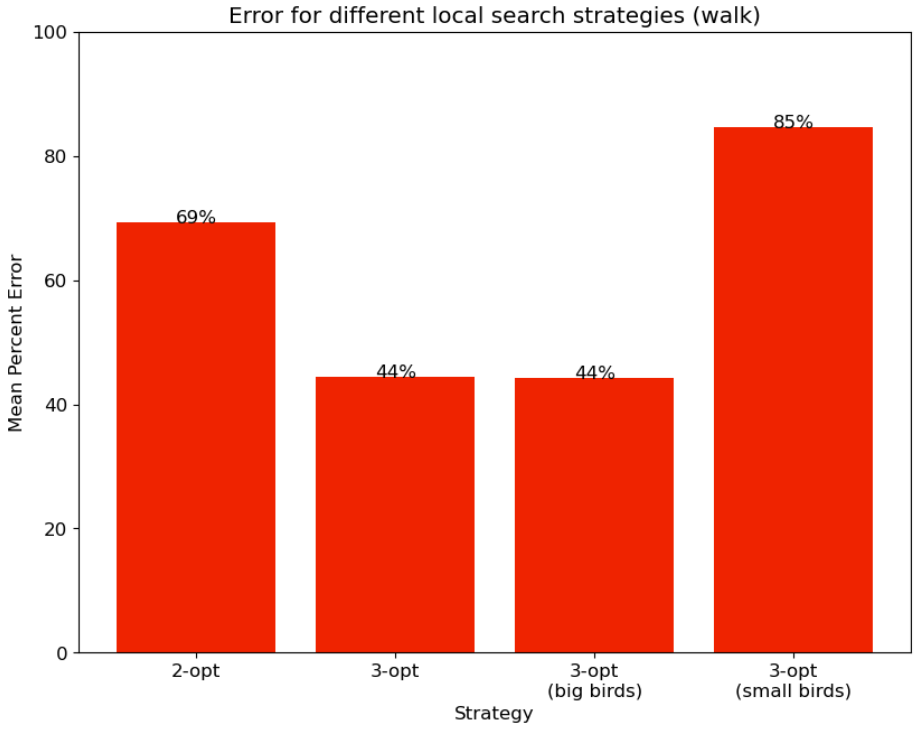
Delegating Responsibility

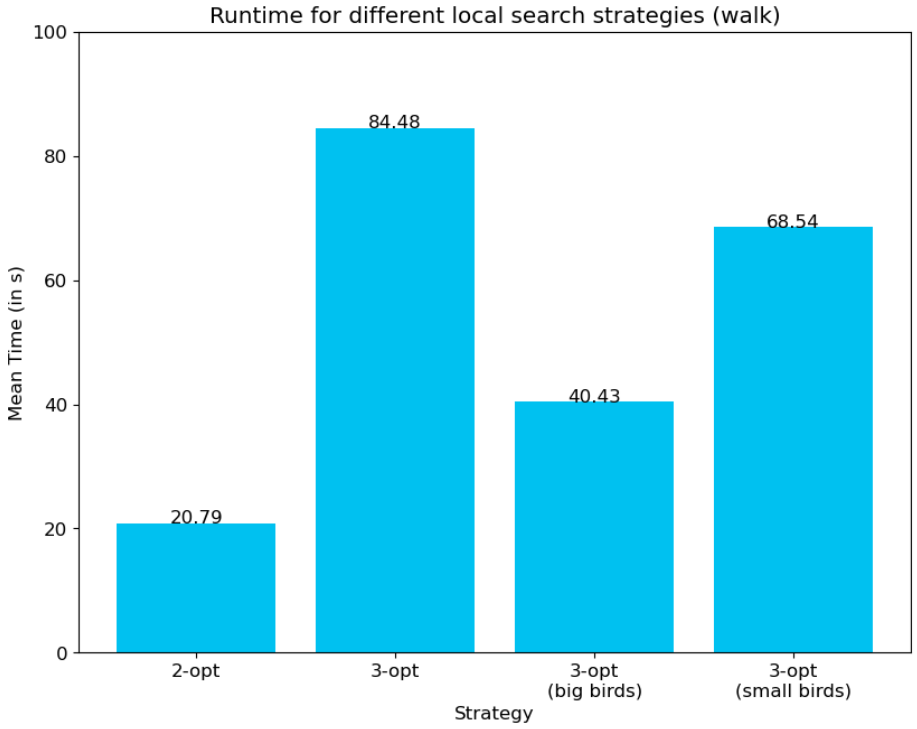


- Seen before: 3-opt (+ sorting for top-b join) yield very high computation effort
- How can one make the algorithm faster while keeping the performance close to before?
- Answer: Allow only big/small birds to perform 3-opt, the other 2-opt
  - Both were tested, but big birds make more sense regarding their “superiority”

Delegating Responsibility







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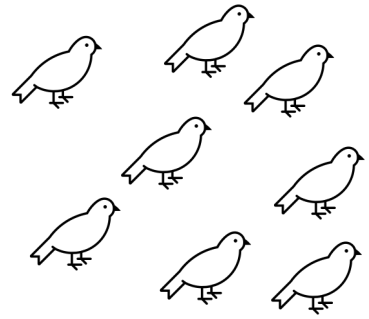
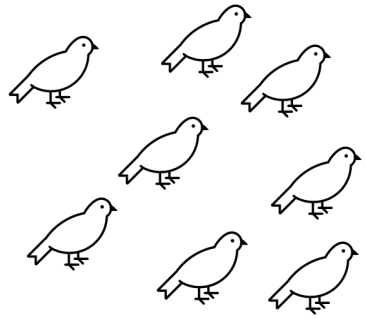
Nearest-Neighbor Initialization

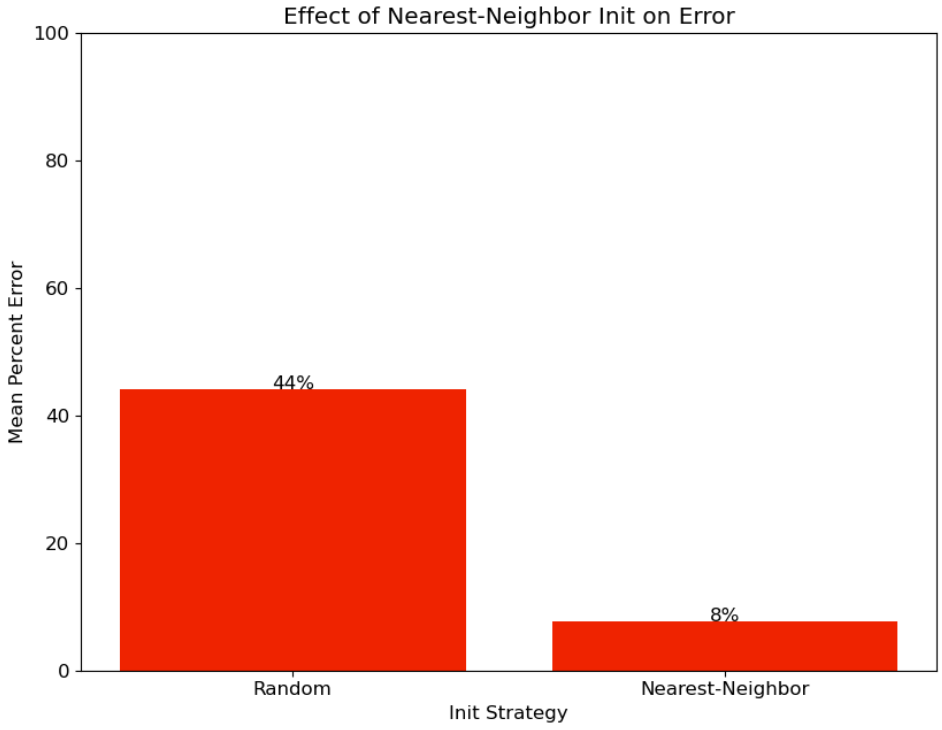


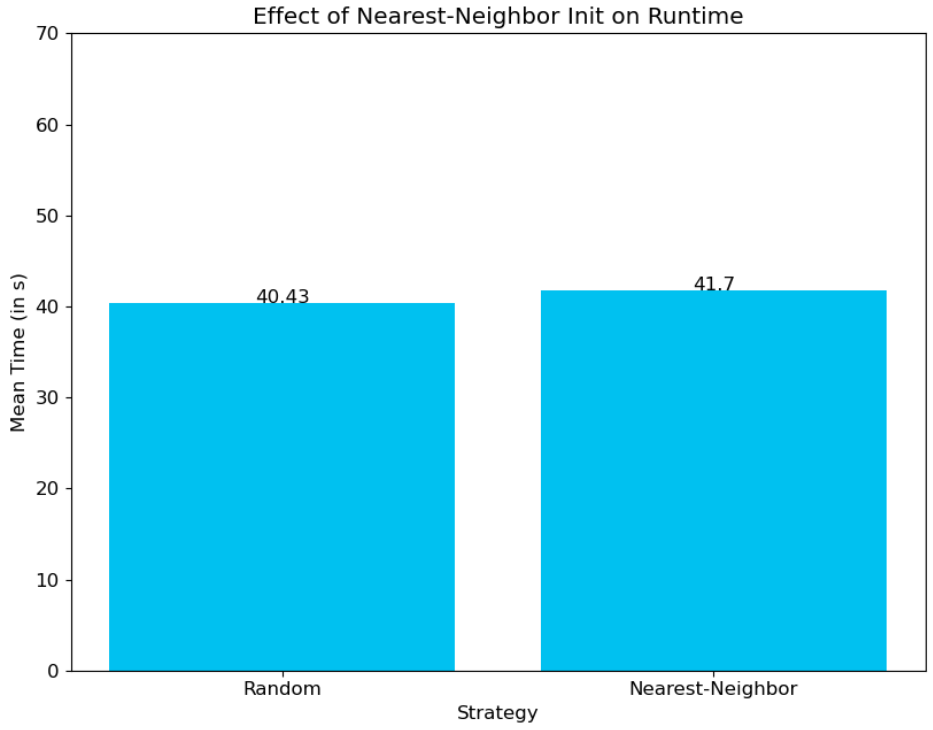
- Instead of starting with random tours, use a simple heuristic for initialization
- Nearest neighbor algorithm
  - Runtime: $O(n^2)$

- Algorithm
  - Start with a random vertex, mark it as visited
  - Add the nearest neighbour of the current vertex, mark it as visited and make it the new current vertex
  - If all vertices are visited the tour is complete

Nearest-Neighbor Initialization







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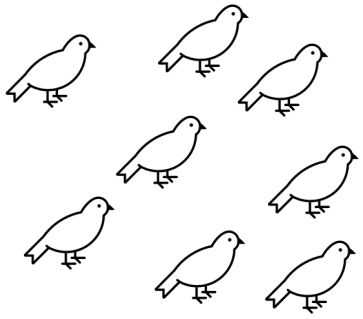
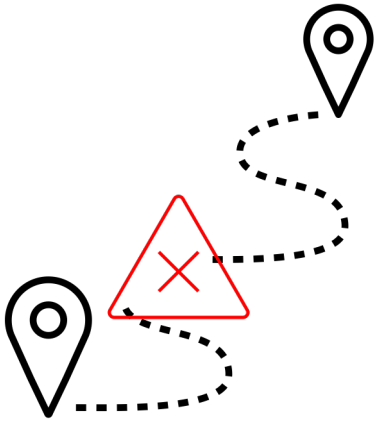
Early Stopping

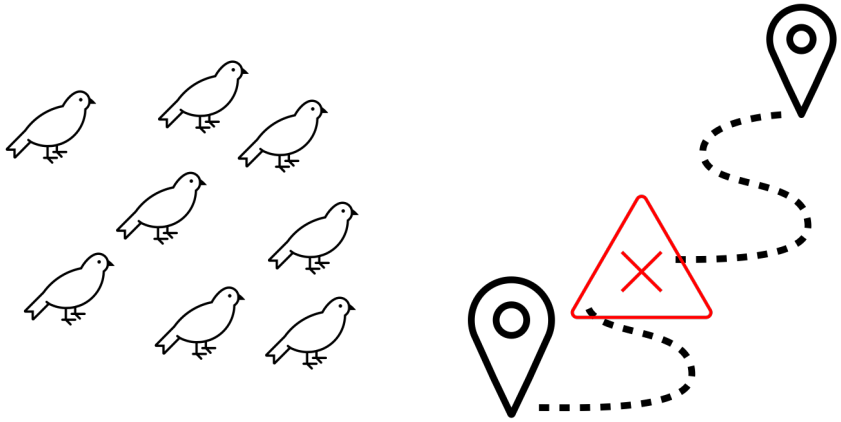


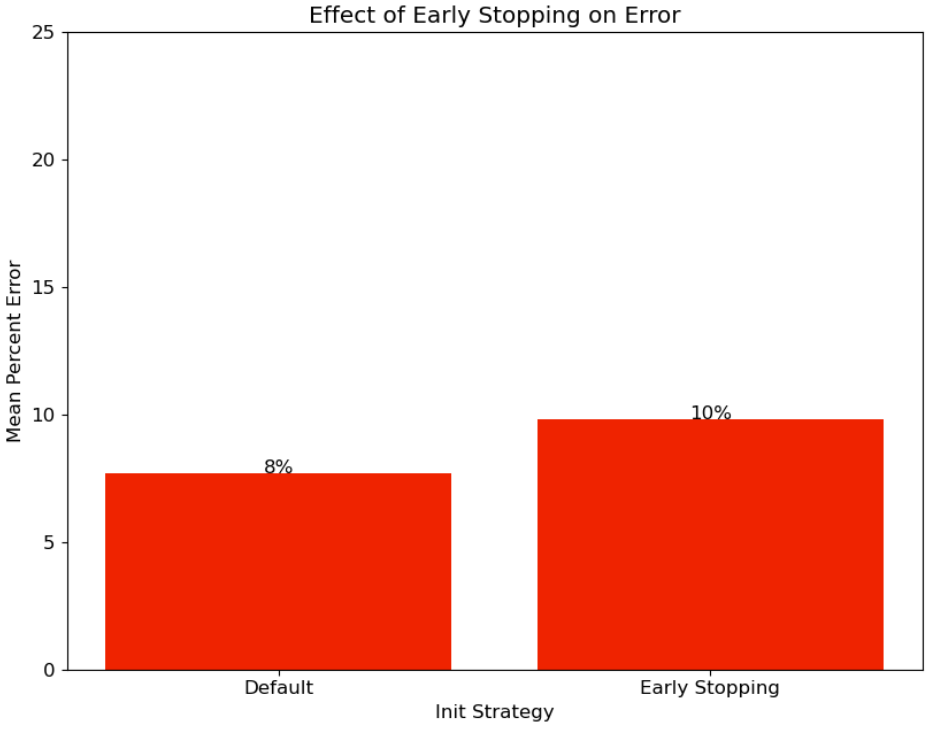


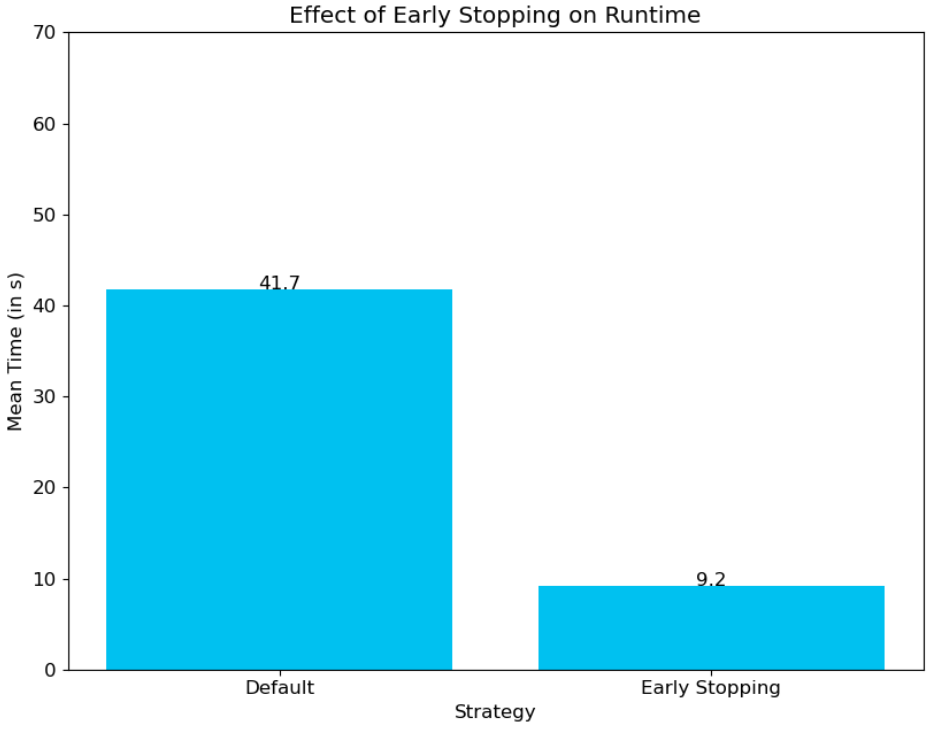
- Algorithm shows very fast convergence behavior
  - Especially for problems with a rather low number of cities
- How many iterations are needed to achieve a good result for a given problem is difficult to estimate
- Therefore, a predefined number of iterations yields unnecessary long computation times that do not improve the results

- One solution is to stop the algorithm, if the current solution(s) do not improve

Early Stopping







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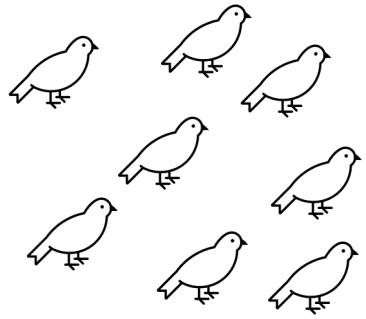
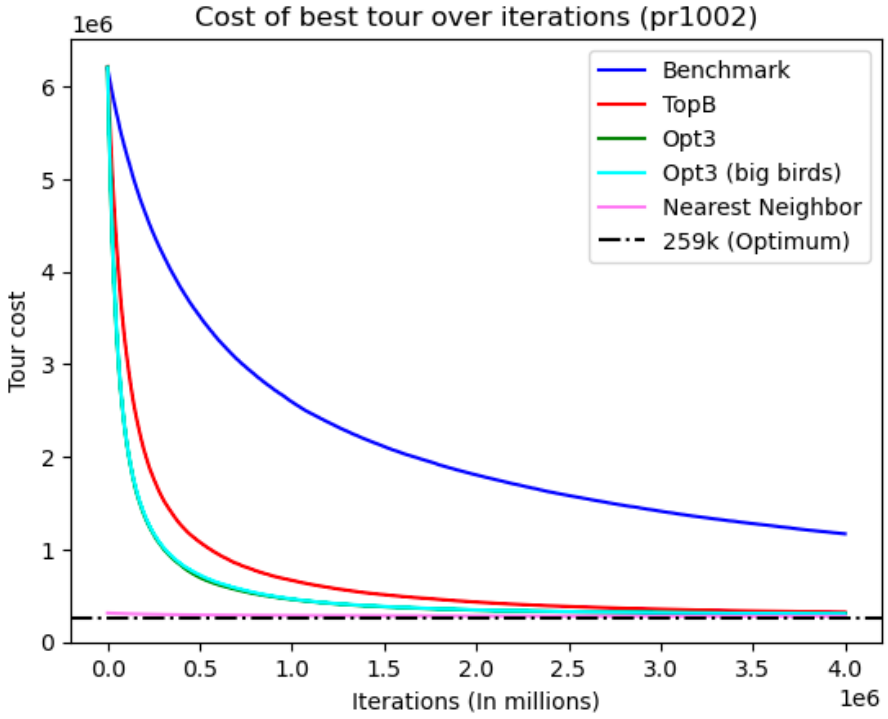
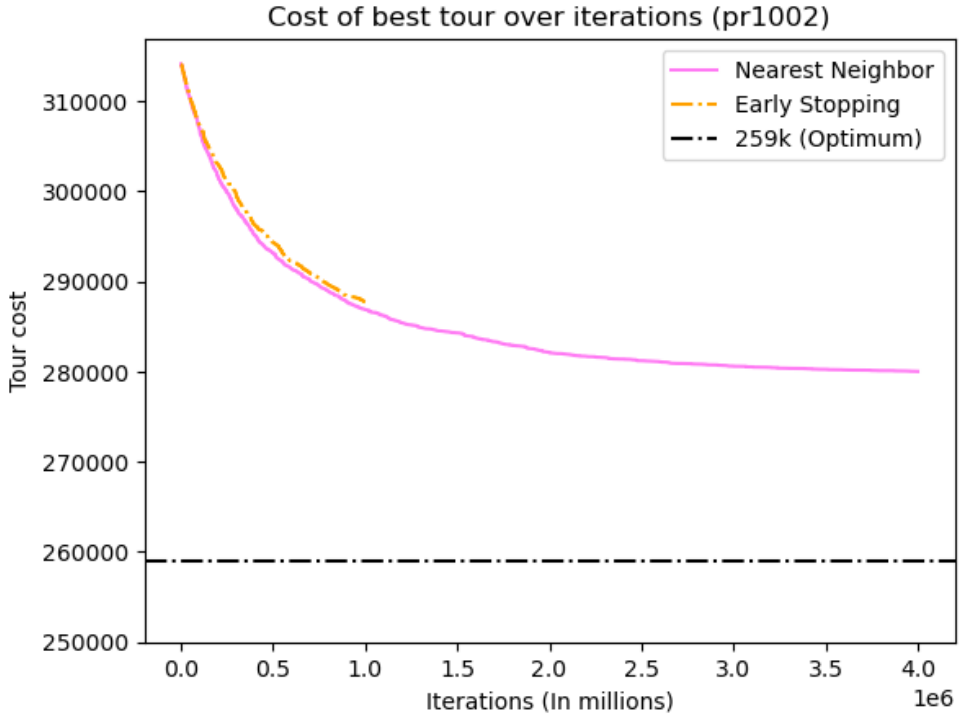
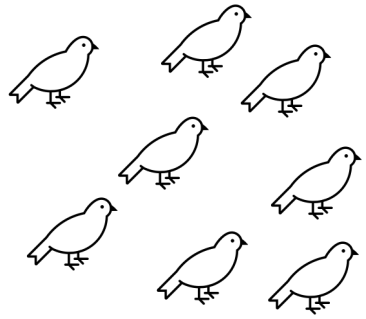
Optimization Behavior

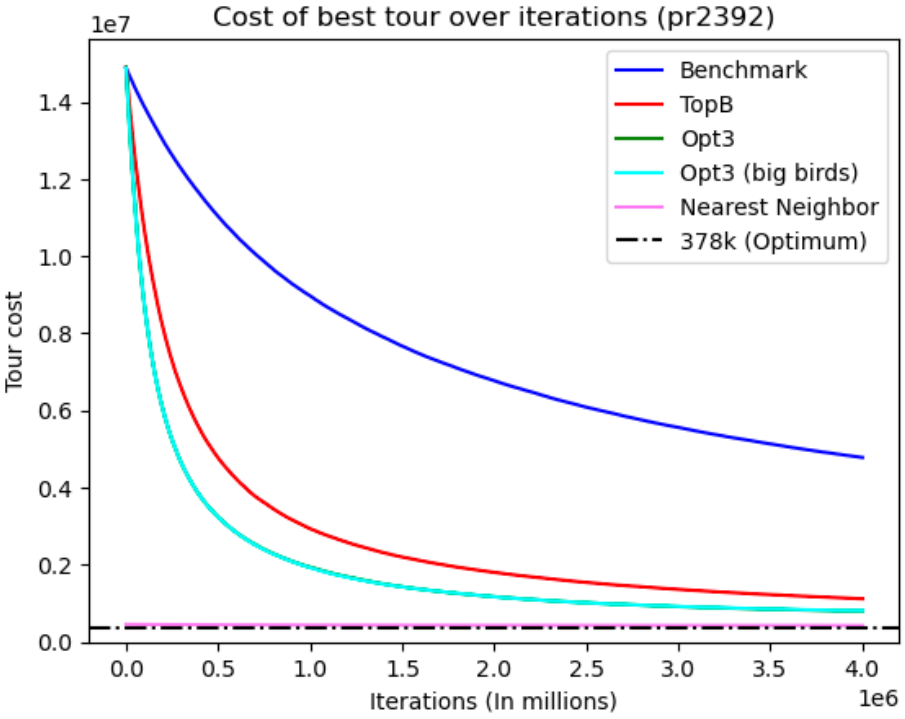


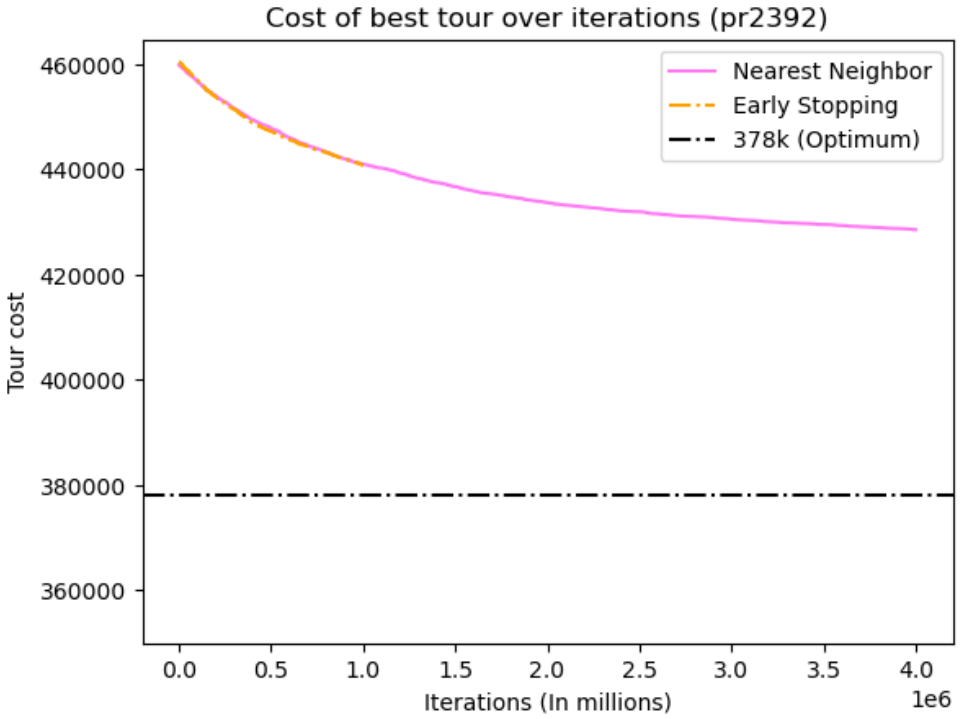




Optimization Behavior







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Metabirds

- How do you choose hyperparameters like move probabilities or small bird ratio?
- Apply an optimization algorithm to find optimal values
- What optimization algorithm? Artificial Feeding Birds!
- A Metabird's position is a value for all probabilities, ratios, etc.
    - Flying generates a random position in the hyperparameter space
    - Walking adds or subtracts a random delta from each parameter
    - Calculating the fitness of a Metabird
        - A TSP solver is instantiated with the hyperparameters of the Metabird
        - Multiple runs solving a TSP are averaged to assess the performance with the current parameters.

Vielen Dank für Ihre Aufmerksamkeit!

Literature

- Jean-Baptiste Lamy. Artificial Feeding Birds (AFB): a new metaheuristic inspired by the behavior of pigeons. Advances in nature-inspired computing and applications, 2019, 10.1007/978-3-319-96451- 5_3 . hal-02264232