Metaheuristic Approaches for Travelling Thief Problem

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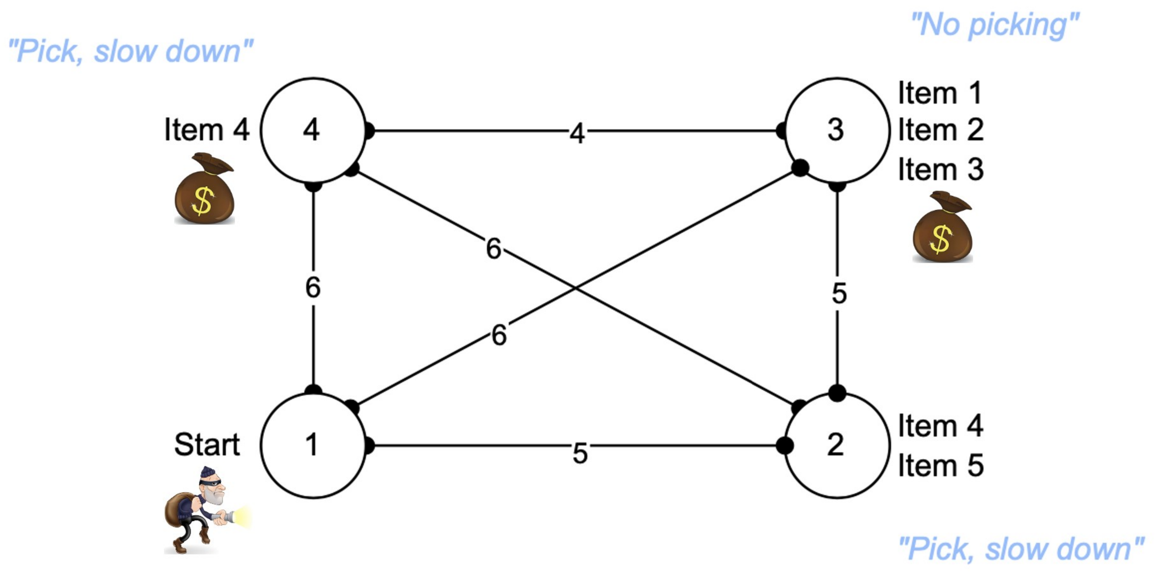
Introduction

Travelling Thief Problem (TTP)

- Traveling Thief Problem (TTP) is combination of Travelling Salesman Problem (TSP) and Knapsack Problem (KP).
- In Traveling Thief Problem (TTP), a person known as a thief starts traveling from a city and travels between designated cities.
- The thief has a knapsack with a limited capacity and wants to collect items which are located in different cities with some weight and value.
- While the thief is collecting the items, thief's speed slows down and the rent he will pay for the backpack increases in direct proportion to the tour time.
- The thief's goal when collecting this item is to maximize his profit without exceeding the capacity of the knapsack.



Formulas:

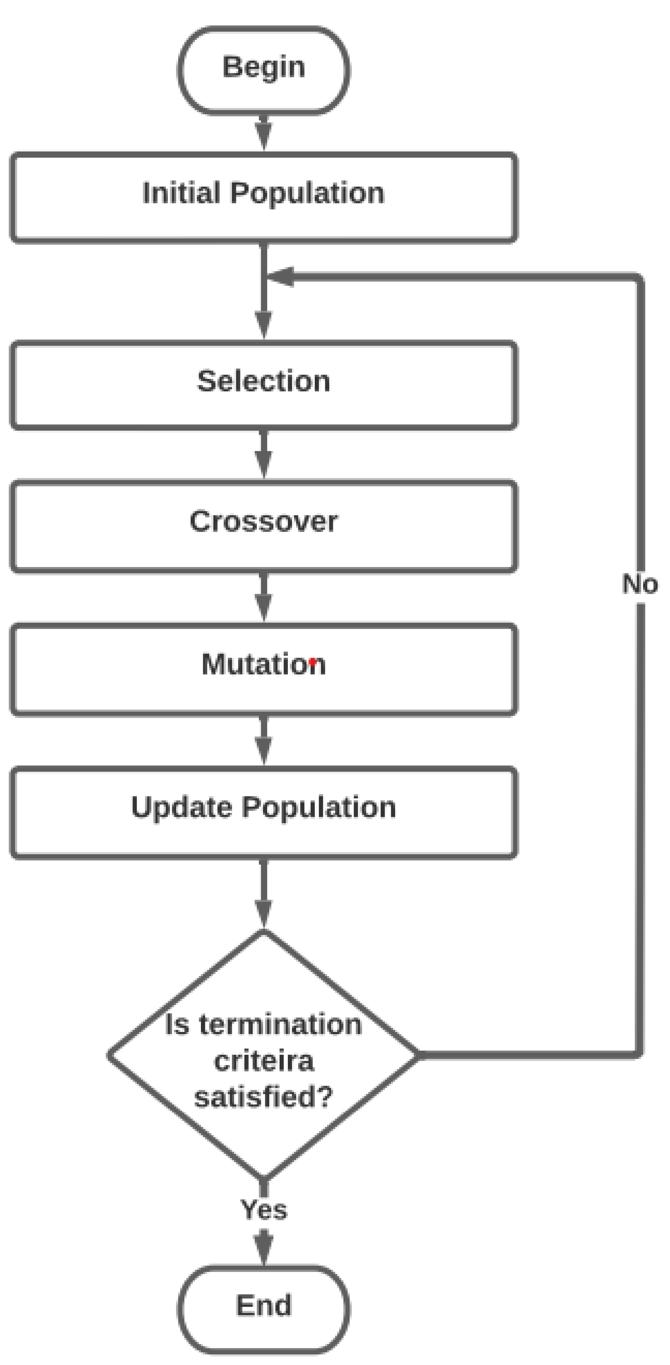
- $Total\ Profit = Total\ Price\ of\ Items - Rent\ Of\ Knapsack * Total\ Travel\ Time$
- $Z(\pi, Y) = \sum_{i=1}^{n}\sum_{k=1}^{m_i} p_{ik} y_{ik} - R \sum_{i=1}^{n} \frac{d_{x_i x_j}}{V_i}$

  $Z(\pi, Y)$ = Total profit
  $p_{ik} = k^{th}\ item\ of\ i^{th}\ city$
  $y_{ik} = k^{th}\ item\ of\ i^{th}\ city\ collected$
  $R = Rent\ ratio\ of\ knapsack$
  $d_{x_i x_j} = Distance\ between\ i^{th}\ and\ j^{th}\ city$
  $v_i = Speed\ of\ thief$
- $V_i = \left(v_{max} - W_c \frac{v_{max} - v_{min}}{W}\right)$

  $v_i = Speed\ of\ thief$
  $v_{max} = Maximum\ speed\ of\ thief$
  $v_{min} = Minimum\ speed\ of\ thief$
  $W_c = Current\ weight\ of\ knapsack$
  $W = Capacity\ of\ knapsack$

Methodology

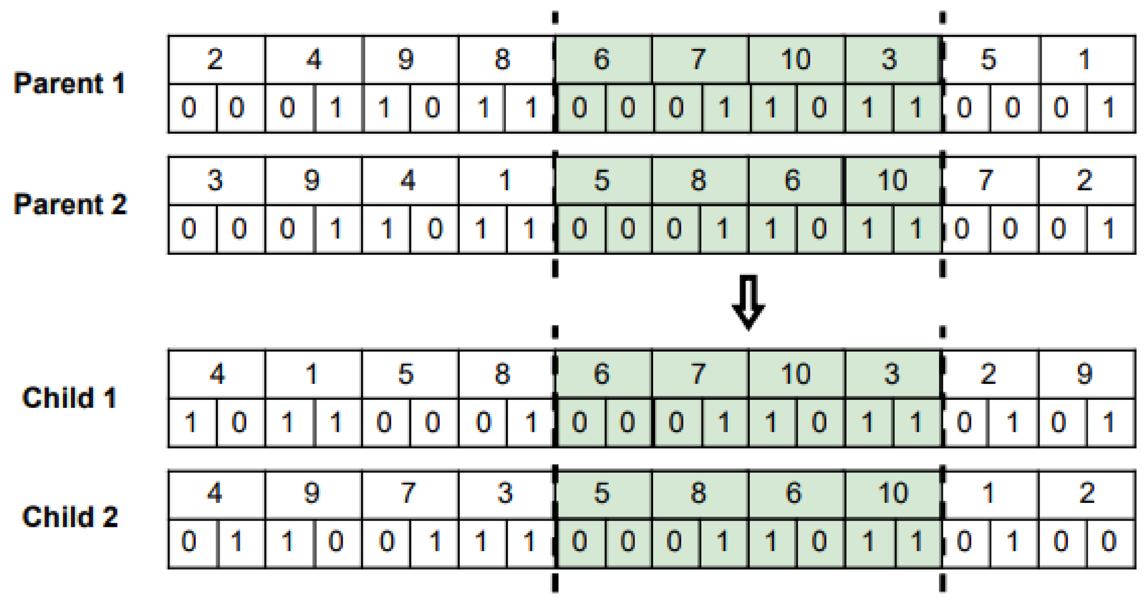
Genetic Algorithm



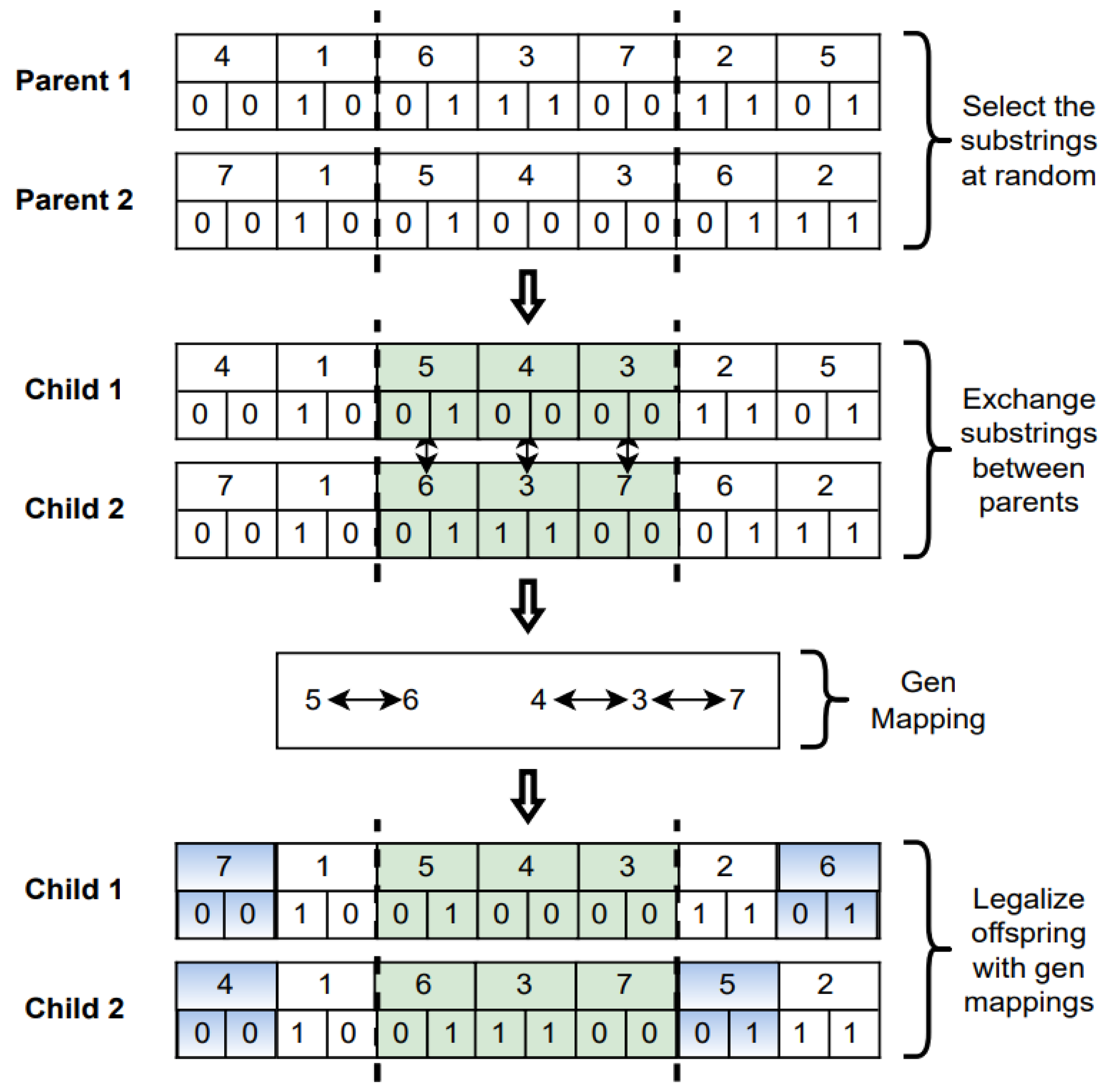
Formulas of Genetic Algorithm

- $Fitness\ value = \frac{1}{total\ profit} + penalty$
- $Penalty = Total\ weight - Knapsack\ capacity$

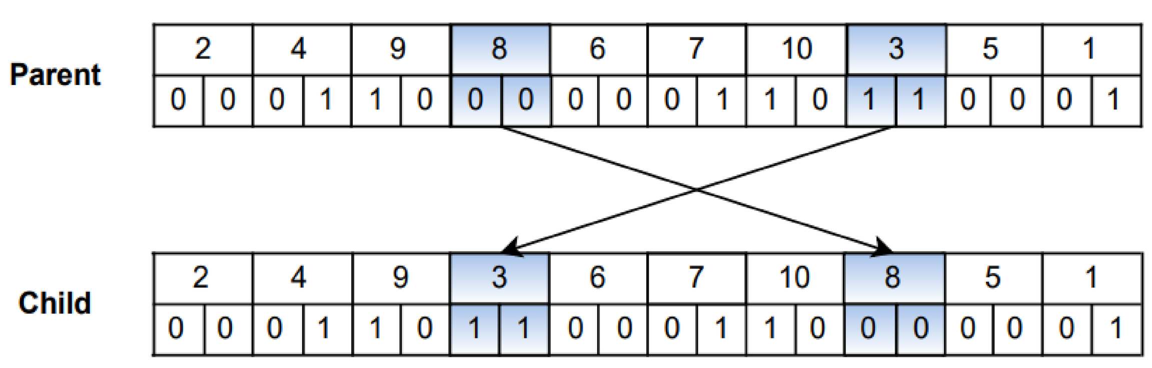
Order Crossover



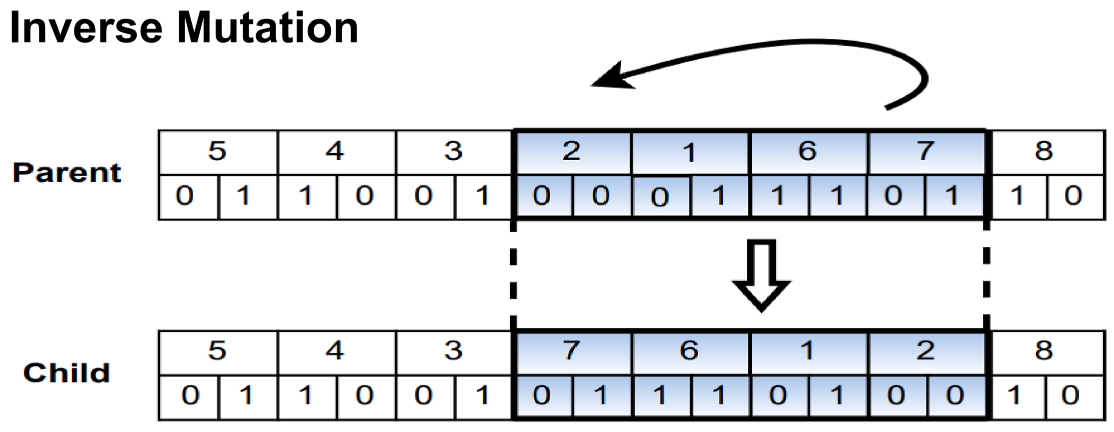
Partially Mapped Crossover



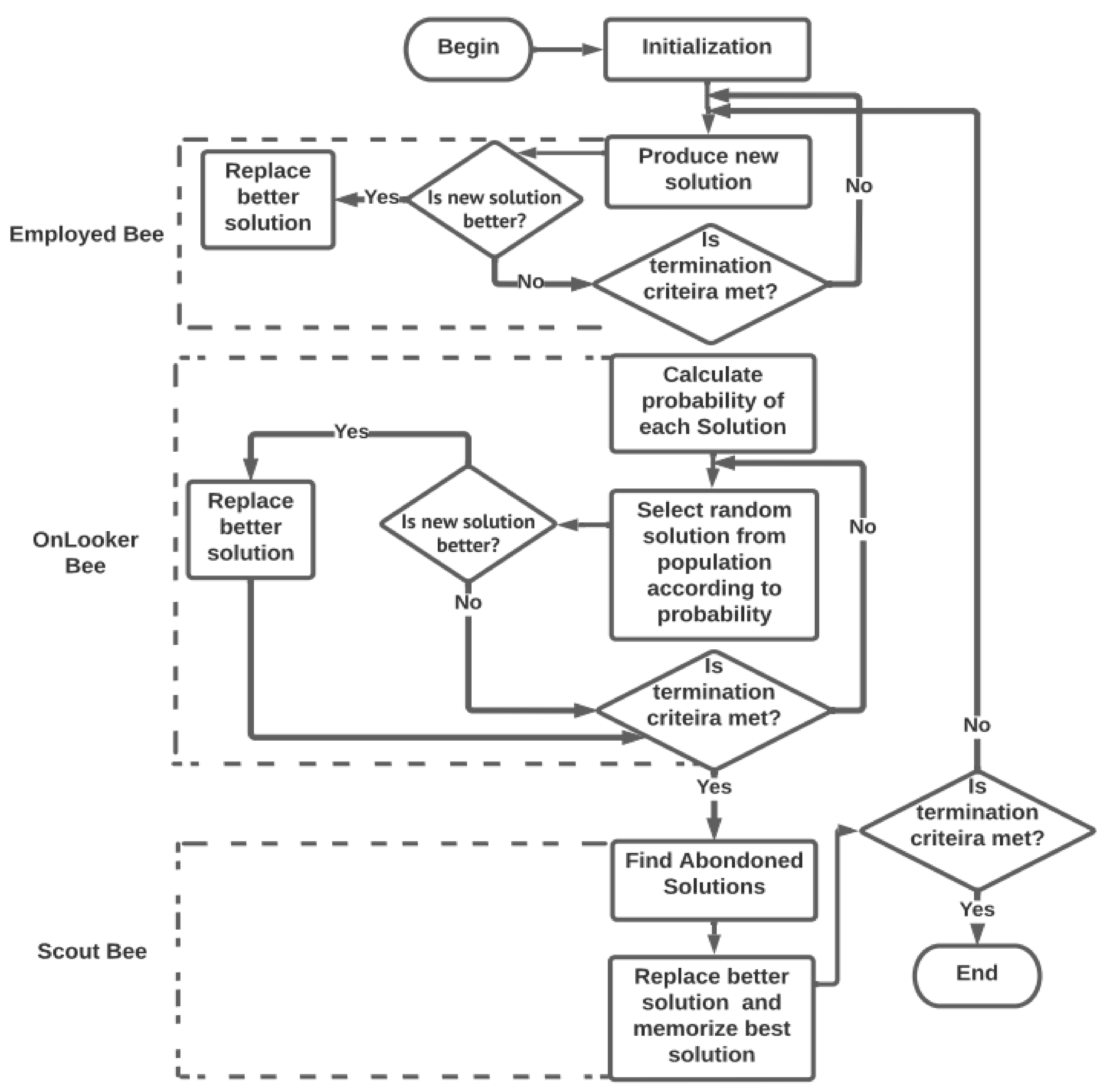
Exchange Mutation



Inverse Mutation



Artificial Bee Colony Algorithm



Formulas of Artificial Bee Colony Algorithm

- $Fitness\ Value = \begin{cases} \frac{1}{1+f_i}, & f_i \geq 0 \\ 1 + |f_i|, & f_i < 0 \end{cases}$
- $Limit = \frac{Colony\ Size\ * City\ Number}{2}$

Test Results

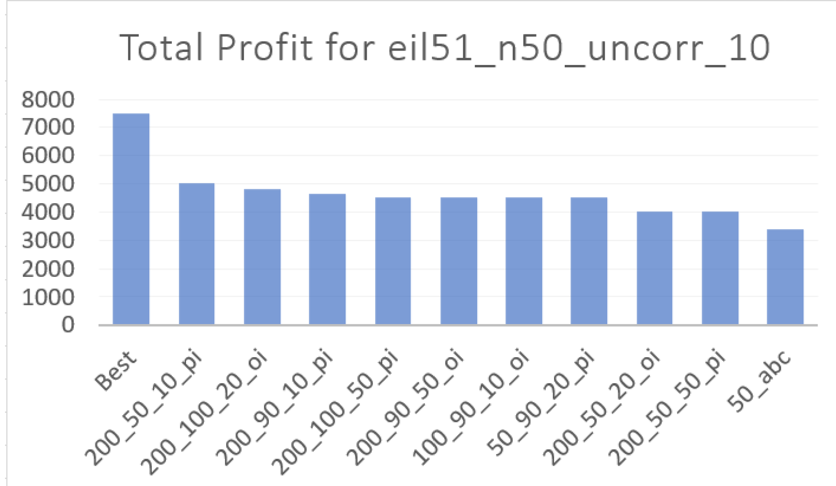
Crossover-Mutation	Average	Standard Deviation
Ordered Crossover - Exchange Mutation	1693.805804	1142.44048
Ordered Crossover - Inversion Mutation	3139.296868	880.1741439
Partially Mapped Crossover- Exchange Mutation	1186.099463	1342.925149
Partially Mapped Crossover- Inversion Mutation	2829.975568	1260.030996

Population Size	Average	Standard Deviation
50	1199.536838	1322.489615
100	2128.640234	1338.700694
200	3308.706205	1329.196218

Crossover Probability	Average	Standard Deviation
50%	2100.600097	1395.631404
90%	2381.111538	1417.082674
100%	2155.171642	1444.034142

Mutation Probabilty	Average	Standard Deviation
10%	2254.96332	1424.747382
20%	2358.642863	1446.718027
50%	2023.277094	1528.573975

Colony Size	Average	Standard Deviation
20	1436.798627	589.626207
50	1668.063683	684.0644453
80	1212.908593	393.5336824



Conclusion

- The parameters of the best solution we have achieved by Genetic Algorithm as follows; "Ordered Crossover - Inversion Mutation Dual", "200 Population Size", "%90 Crossover Probability", "%20 Mutation Probability".
- When we compare the results we have obtain, we have observed that the results of Genetic Algorithm are better than Artificial Bee Colony Algorithm.
- As a future work, we plan to run these algorithms for datasets with a larger number of cities and a larger number of items in a city.

References

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Used Technologies

GitHub

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