IM39003

Assignment 7: *Ant Colony Optimization*

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ACTIVITY - 1

This section summarizes the results of experiments conducted to study the effect of change in various parameters on the convergence of the Ant Colony Optimization :

1. Change the number of iteration 50, 100, 200, 400 and find optimal iteration number

2. Update the pheromone by changing the number of ants 10:20:100.

3. Change Pheromone Exponential Weight α from 1 to 0.5, 1, 2, 3

4. Change Heuristic Exponential Weight β from 1 to 0.5, 1, 2, 3

5. Change evaporation Rate(ρ) : 0.01:0.02:0.1

6. Change Q (multiplier) value 10 :1:15 times proportionate to number of ant

Default set of parameters :

Parameter	Value
Maximum Iterations	300
Number of ants	40
Pheromone Exponential Weight α	1
Heuristic Exponential Weight β	1
evaporation Rate(ρ)	0.05
Q multiplier	15
Q	1

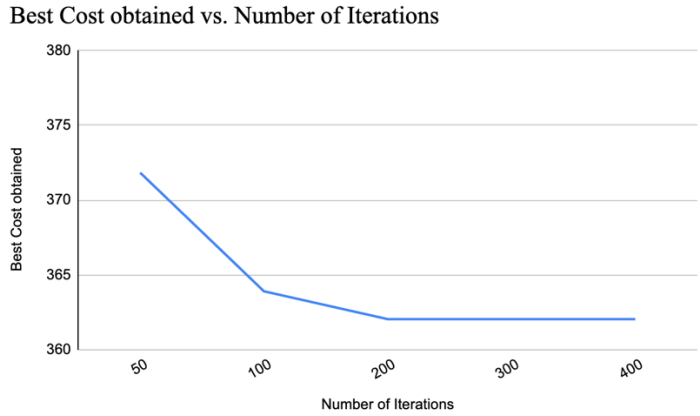
Parameters are compared on the basis of the following two points (in that order of importance) :

1. **Quality of the optimal solution obtained**
2. **If more than one case yields the best cost, the parameter that ensures faster convergence will be chosen**

1. Change in number of Iterations :

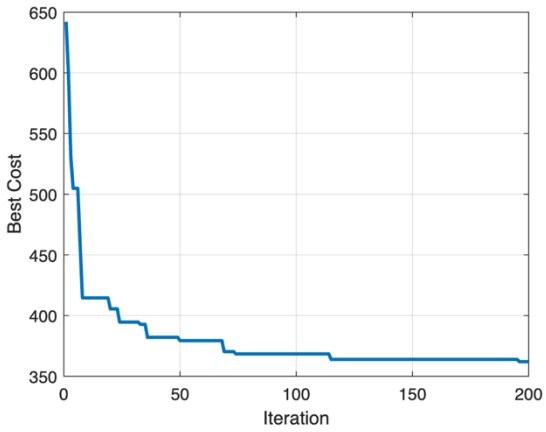
Number of iterations	Objective function value (Best cost)
300	362.038
50	371.8383
100	363.897
200	362.038
400	362.038

Visualizing the variation of best cost obtained with change in maximum iterations

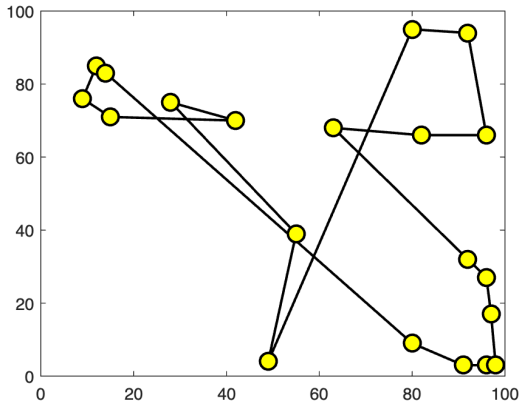


We see that the best cost obtained remains constant for all number of iterations >= 200. Considering the fact that increasing the number of iterations increases the cost of computational resources, we conclude that the **best value for this parameter is 200.**

At number of iterations = 200 :



Best cost v/s Iterations

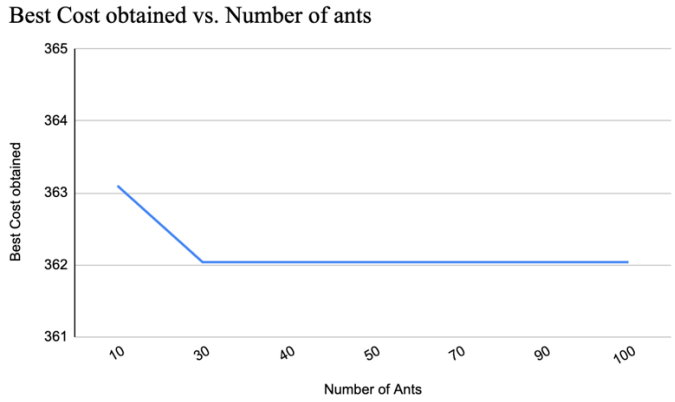


Best cost tour obtained in 200 iterations

2. Change in number of ants :

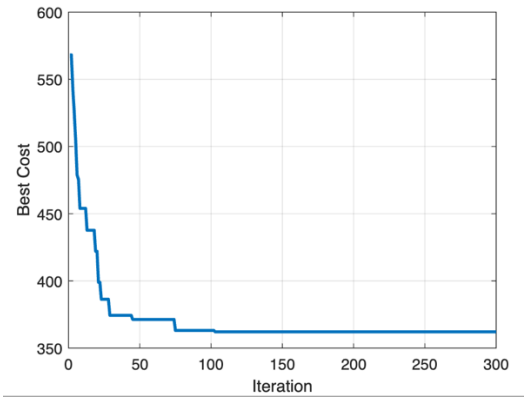
Number of ants	Objective function value (Best cost)
40	362.038
10	363.1002
30	362.038
50	362.038
70	362.038
90	362.038
100	362.038

Visualizing the variation of best cost obtained with change in number of ants

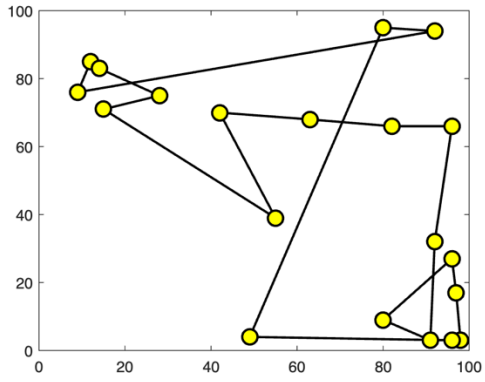


We see that the best cost obtained remains constant for all number of ants >= 30. Considering the fact that increasing the number of ants increases the cost of computational resources, we conclude that the **best value for this parameter is 30.**

At number of ants = 30 :



Best cost v/s Iterations

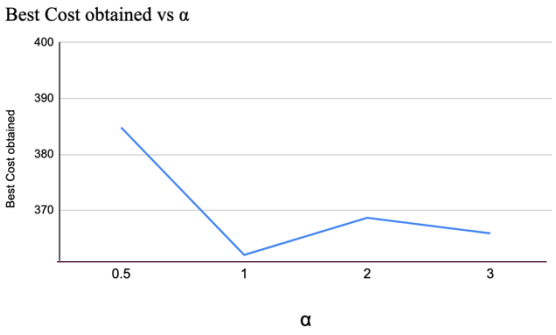


Best cost tour obtained with 30 ants

3. Change in pheromone exponential weight α :

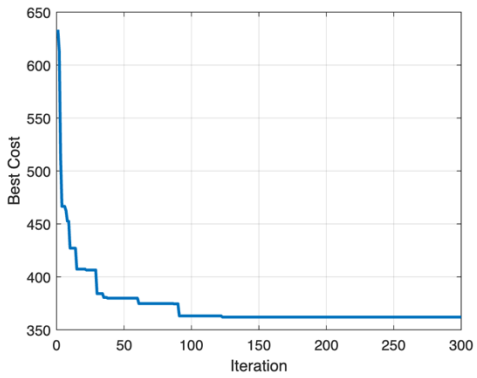
Pheromone exponential weight α	Objective function value (Best cost)
1	362.038
0.5	384.8179
2	368.6801
3	365.897

Visualizing the variation of best cost obtained with change in α

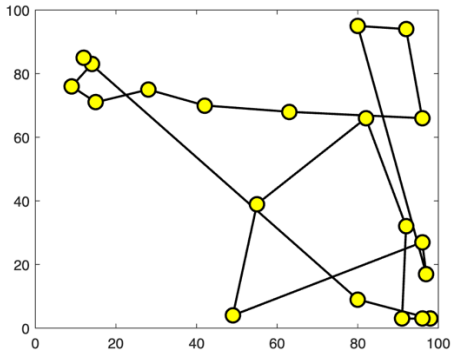


Best value for this parameter is 1.0.

At $\alpha = 1.0$:



Best cost v/s Iterations

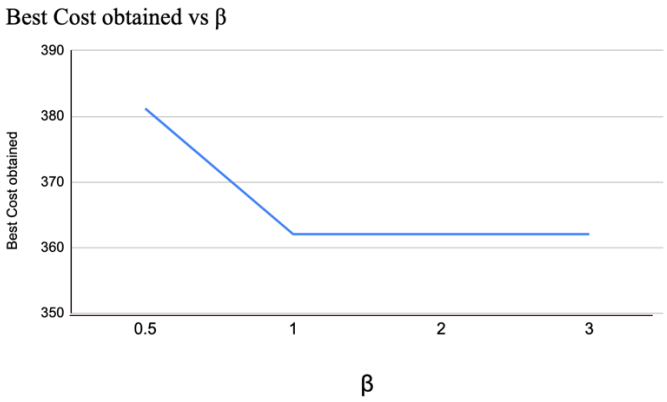


Best cost tour obtained at $\alpha = 1.0$:

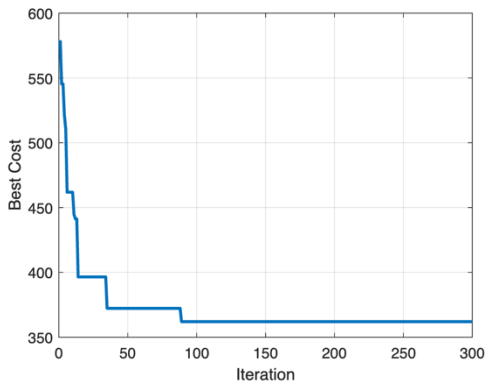
4. Change in Heuristic Exponential Weight β:

Heuristic Exponential Weight β	Objective function value (Best cost)
1	362.038
0.5	381.1887
2	362.038
3	362.038

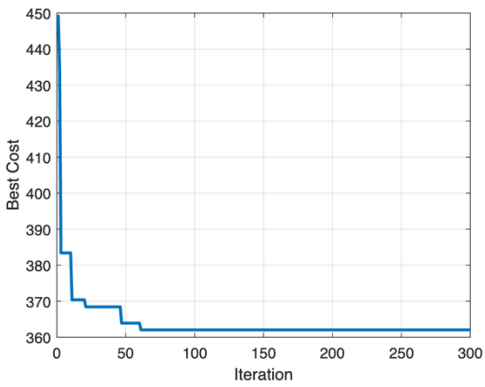
Visualizing the variation of best cost obtained with change in β



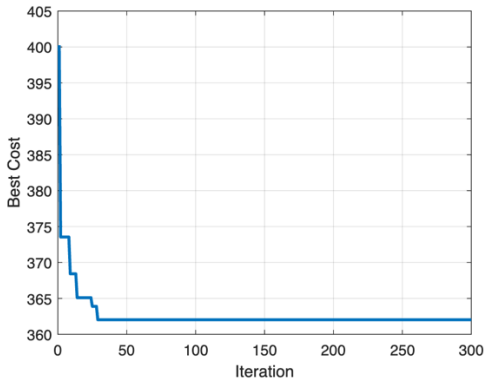
We see that the best cost obtained remains constant for all values of β >= 1.0. Therefore, we now compare their convergence rates



At β = 1



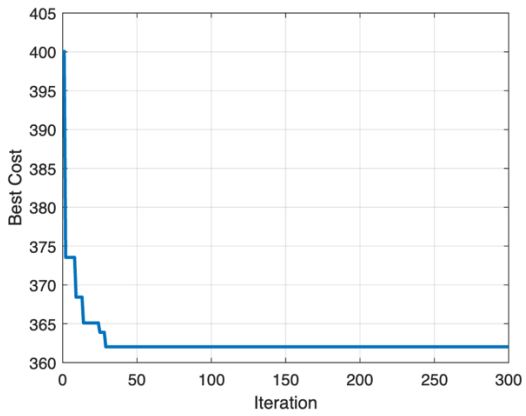
At β = 2



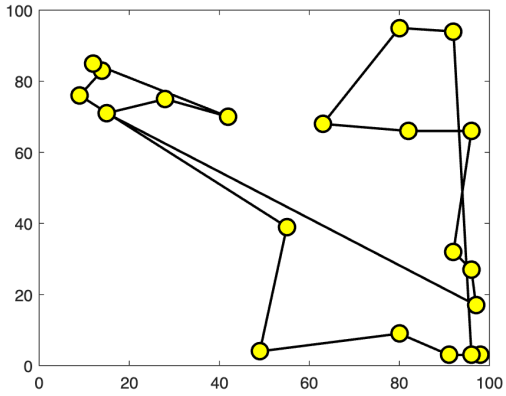
At β = 3

We see that the fastest convergence occurs at β=3(under 50 iterations). **Best value for this parameter is 3.**

At $\beta = 1.0$:



Best cost v/s Iterations

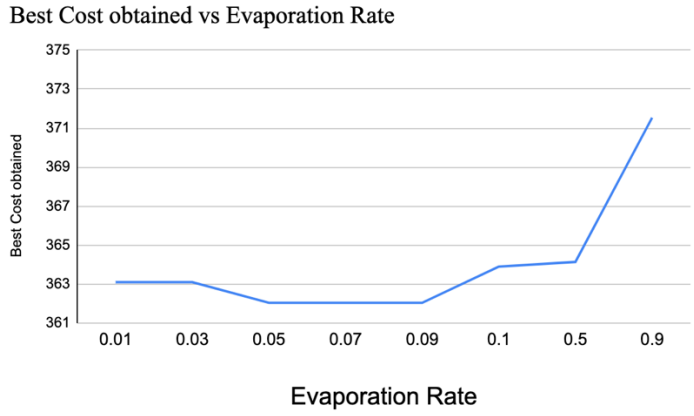


Best cost tour obtained at $\beta = 3.0$:

5. Change in Evaporation Rate(ρ):

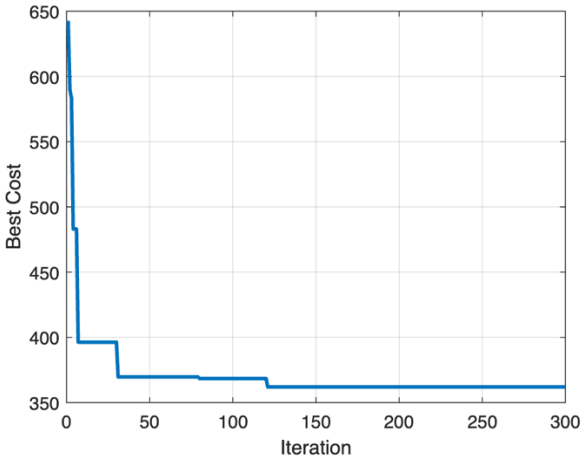
Evaporation rate ρ	Objective function value (Best cost)
0.05	362.038
0.01	363.1002
0.03	363.1002
0.07	362.038
0.09	362.038
0.10	363.897
0.50	364.1392
0.90	371.5369
0.99	365.897

Visualizing the variation of best cost obtained with change in α

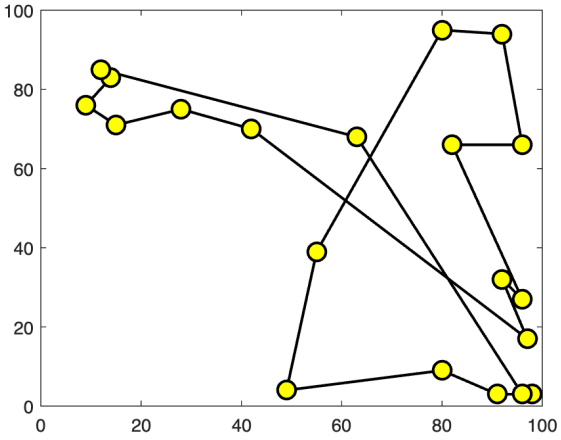


It was observed that the best cost obtained decreased as the evaporation rate went from 0.01 to 0.05. It was also seen that the best cost starts increasing when evaporation rate was being increased beyond 0.09. Therefore, this particular seems to have a parabolic relationship with the best cost obtained. **We fix the best value of evaporation rate = 0.05.**

At evaporation rate = 0.05:



Best cost v/s Iterations

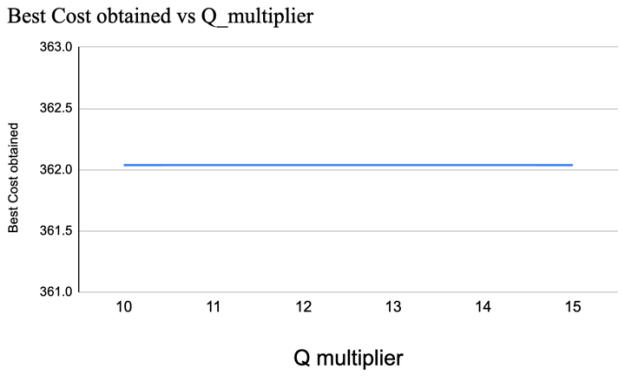


Best cost tour obtained with 30 ants

6. Change in Q_multiplier value :

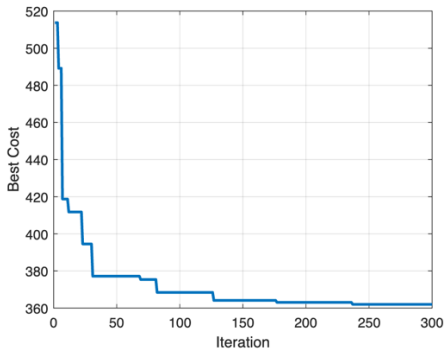
Number of iterations	Objective function value (Best cost)
15	362.038
10	362.038
11	362.038
12	362.038
13	362.038
14	362.038

Visualizing the variation of best cost obtained with change in Q multiplier value :

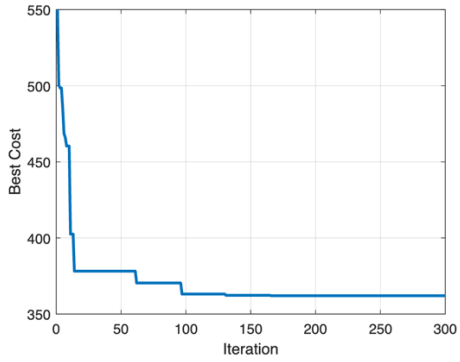


The best cost obtained remained constant for all the values of Q_multiplier considered.

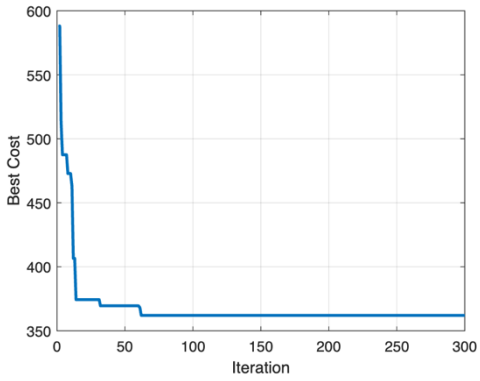
But it was observed that the quickness of convergence varied with change in Q_multiplier. Higher values of the parameter ensured quicker convergence.



At Q_mult = 10, convergence > 200 iterations



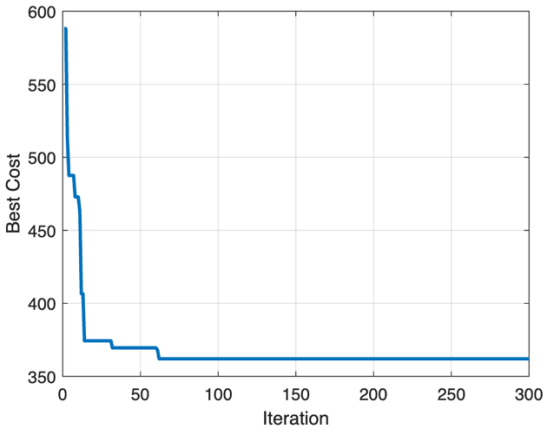
At Q_mult = 13, convergence > 100 iterations



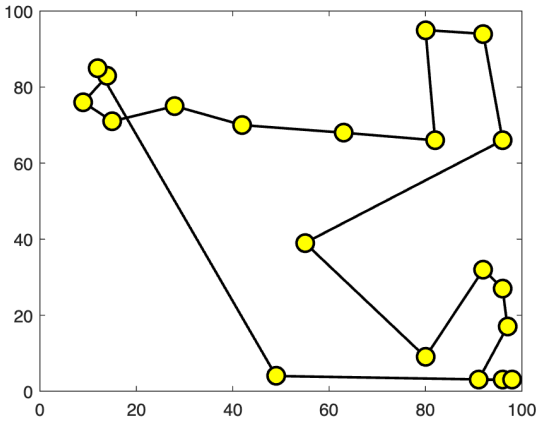
At Q_mult = 15, convergence > 50 iterations

Since Q_mult = 15 ensures fastest convergence, we take that to be the best possible value for Q_mult among the alternatives considered.

At Q_multiplier = 15 :



Best cost v/s Iterations



Best cost tour obtained at Q_mult = 15

BEST set of parameters obtained among the set of choices considered :

Parameter	Value
Maximum Iterations	200
Number of ants	30
Pheromone Exponential Weight α	1
Heuristic Exponential Weight β	3
evaporation Rate(ρ)	0.05
Q multiplier	15

Conclusions :

1. Increasing the number of iterations is improving the quality of convergence, as with any optimization algorithm. The algorithm was seen to converge by 200 iterations.
2. Number of ants which is analogous to population size in any evolutionary algorithm denotes the number of solutions explored at each iteration. Increasing the number of ants increases the exploration capability of the algorithm. This trend was seen when the number of ants was increased gradually from 10 to 30. Number of ants greater than 30 was seen to reach the optimal at all costs.
3. There was no proper trend observed when the pheromone exponential weight α was varied. The optimal was obtained at α=1.0
4. It was seen that the algorithm converged to optimal for all values of heuristic exponential weight β greater or equal to 1. So the convergence rate of the algorithm was compared for β=1,2,3. It was seen that higher values of β yielded much faster rates of convergence. Therefore, the best value of β among the ones considered is 3.
5. A mixed trend was observed when the evaporation rate ρ was varied. The cost function reduced till $\rho = 0.05$ (optimal between 0.05-0.09) and started increasing again for $\rho > 0.09$. Therefore, $\rho = 0.05$ was taken as the best value for the parameter.
6. All 6 values of Q_multiplier considered reached the optimal value. Therefore, these values were compared based on the rates of convergence observed in each case. It was seen that increased the value of Q_multiplier results in faster convergence. Thus, the optimal value of Q_multiplier was fixed at 15.

ACTIVITY - 2

This section summarizes the result of job scheduling problem solved using ant colony optimization.

Job	Processing time	Due time
1	6	18
2	2	6
3	3	9
4	4	11
5	5	8

```
Iteration 1: Best Cost = 6
Iteration 2: Best Cost = 6
Iteration 3: Best Cost = 6
Iteration 4: Best Cost = 6
Iteration 5: Best Cost = 6
Iteration 6: Best Cost = 6
Iteration 7: Best Cost = 6
Iteration 8: Best Cost = 6
Iteration 9: Best Cost = 6
Iteration 10: Best Cost = 6
Optimal Schedule
2  5  3  4  1
Minimum Tardiness = 6
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