Solution optimization of ACO in TSP by modification of parameters

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***Abstract*— Ant Colony Optimization is a optimization algorithm used to solve complex optimization problems. The ACO algorithm implementation was inspired the biological behavior of ants which involve the large population with indirect communication via pheromones trails. There are few solutions were discussed on implementing ACO algorithm in real life in the literature. Based on the behavior of real ants, Ant Colony Optimization algorithm represented good results to several well-known complex problems, such as the travelling salesman problem. One of the main objectives of the TSP is to find the optimal route to visit all the cities or location with a condition of travelling each city only once. In this journal paper, few ACO implementation in real life analyzed and how to obtain best path by tuning the parameters.**

***Keywords*— ant colony optimization, travelling salesman problem, algorithm**

I. Introduction

Ant Colony Optimization Algorithm is one of most popular algorithms used to solve computational problems by investigating all the possible efficient paths on the graphs. It is developed based on the real ant colony behaviours which involves large population and indirect form of communication of the colony agents to find their food sources efficiently (shortest distance) based on the pheromones trails.[1] The pheromone trails are basically the way of ants communicate within their colonies and there are not only being used to inform the shortest path to the food source but also for feeding and mating purposes.[2] To picturize how this any colony works via the pheromones trails, just image there is multiple ways to get from city A to city B and the ants will start to move in the random paths from point A to point B while memorizing the path distance and never travel in the same path that has been travelled before. The ants releases pheromones while they are on the way. The ants tend to choose their path based on two rule which are the concentration of pheromones and heuristic information. The higher the concentration of the pheromones and heuristic value, the higher the chances of the ants to choose that path. Once all the paths have been covered by the ants the pheromones on the paths are updated.[3].

In addition, now that the concept of how the ants utilize pheromones trails to obtain shortest distance to the food source is understood, it will be much easier to understand and implement similar concept in the ACO algorithm. A set of software agents will be computing to find the best path on the weighted graph. The software agents will incrementally build the solutions by moving on the graph with biased construction process based on the pheromone model , in this case represents the edges and nodes (graph components).[3] The criteria mentioned above best describes the travelling salesman problem. TSP is a common optimization problem in graph theory where the nodes represent the cities and edge represents the routes. The travelling salesman requires to travel to all the cities with the most efficient path to minimize the distance travelled. This is an perfect example of an non-polynomial complete problem. [4]

II. Literature Review

A. Similar Project

There are a few of researches that are related to the topic that we are discussed in this paper. The findings in the appropriate papers can leads to a better view on how to modify the parameters in the Ant Colony Optimization algorithm to get a better solution route in Travelling Salesman Problem.

The research paper of [5] had investigate about the parameters tuning of ACO algorithm using PID controller for the induction motor. The controller is used to control the parameters like number of nodes, number of ants, maximum iteration time, maximum distance for each ant's tour and the pheromones versus distance impact in an induction motor. The study had found the best speed for the induction motor to increase the performance of the motor and reduce the waste of energy and time by using the optimal value in each of the parameters.

In the research made by [6], the quality of TSP problem is impacted by the parameters in the ACO algorithm. Therefore, an experiment with the testing of different values in each parameter to form graphs and charts so that the researchers can analysis the range of optimal value which gives the optimal solution for different type of instances used. The results are then showing the correct values of 3 parameters using the interval from 2 values x and y which presented in the form of <x; y>.

[7] had discussed about how to control the parameters of ACO for dynamic fuzzy logic application in the autonomous mobile robot. The adaptive control on the parameter alpha in the ACO algorithm made the fuzzy controller to be more diversity by having a bigger coverage of variant in the logic application. There is a dynamic change recorded when the alpha parameter changed in ACO algorithm.

B. Methodology / Approach

In this part, the overview of the previous researches and studies that related to Ant Colony Optimization approach to the problems. These techniques had contributed to solve the Travelling Salesman Problem in the related sector will be used as reference to lead to a better work in this paper.

[8] is talk about the approach of ACO algorithm towards the reliable of wireless sensor network (WSN). WSN is the key of the development of Internet of Things (IoT) which will determine the mission time of an IoT application through the time interval of the network operation. Therefore, the ACO algorithm had helped to minimize the cost of WSN deployment by finding the shortest interference route. It reduced the wastage of bandwidth and energy consumption of the mission time. In the experiment result in [1], ACO had obtained an average 20% higher quality of solutions on solving the different problem instance in WSN compared with the Greedy Heuristic's solution.

In a research work, [9] proposed to investigate the approach of ACO towards the satellite broadcast scheduling (SBS) problem. As there are more satellites exceeded in the space, the satellites need to work simultaneously to prevent signal interruption. Hence, the ACO algorithm with the hypercube framework can make the broadcasting task of the satellites' alternative signal routes more easily to be managed by controlling the pheromones value of the ACO algorithm. These had increased the efficiency of time and quality through the evaluation of benchmark sets with the usage of statistical techniques.

Through the research of [10], it stated that robot path planning can also can be solved with the approach of ACO algorithm. The ACO algorithm had provided the robot a good result of navigation by giving the current location of the robot, avoid obstacles in the route and determine the shortest route to the destination. However, it takes more time to make iteration processes. Therefore, the research is concluded with finding of solving way to prevent the ants stuck in one point which will prevent the ant reaching the goal destination.

C. Conclusion/Recommendations

The ACO algorithm had solve many types of travelling salesman problem in every sector which it can provide the optimal route for the wireless sensor network, satellite broadcasting and robot path planning.

To get a better solution route from the ACO algorithm in TSP problem, we need to find out the optimal value of the parameters for the TSP problem. The parameters that we will need to be examined is the number of epochs, number of ants per epochs, evaporation rate, pheromone impact and distance impact.

In this paper, the ACO algorithm will be used to find the best route in the Bavaria city which controlling the related parameters stated previously. The discussion and result of the experiment will also be done in this paper for the reference of parameter tuning in ACO algorithm.

III. Material and Methods

A) Ant Colony Optimization

Ant Colony Optimization algorithms has been implemented to solve Travelling Salesman Problems with optimize solution. The source code of the algorithms does not create by researchers. The source code used in this paper belong to LazoCoder from GitHub. All researchers has done is show the effect to the result by modifying parameters. The parameters has included Ants per epochs, Epochs (Number of epoch), Evaporation rate, Alpha α (pheromone impact), Beta β (distance impact).

B) Software Requirement

- Java SE
- NetBeans / other IDE

This is a Java based source code and researchers has run the code by NetBeans as integrated development environment. However, this code is able to run in any Java IDE and also can be execute in command prompt of the operating systems. If user used Java IDE as the tools to modify just edit the parameters in the main class to view the change. If user used CMD as the tools, user will need to set up the path and insert "java Main -p" to run the program with customize parameters.

C. Hardware Requirement

There is not have any hard requirement to run the code. However, researchers have recommended to using a device at least have a CPU with 5th generation (Intel Core I5) processor and 8gb RAM to run this code. As there is always the needs of calculation and memory space to run the algorithms.

IV. Algorithm Implementation

In this study paper, we experimented the ACO algorithm which is from [11] is solving the travelling salesman problem through parameter tuning to study the best routing of ACO. TSP is the basic operational research which aimed to visit all the nodes (cities) in the instances with the shortest route and travel back to the origin node at the end. [6] There are 5 type of parameters (ant per epoch, number of epochs, evaporation rate, alpha (pheromones impact) and beta (distance impact)) which we can modify to find out the optimal value of the ACO algorithm. The TSP instance use for this research is bays29.tsp which collected from the TSPLIB. [12]

The ants per epoch parameter is the number of ants that available in each generation/epoch. The colony of ants will make decision on each decision point. Each ant will leave the pheromones in the route so that the other ants can follow the trail route leave by the previous generation/epoch. Besides that, the number of epoch parameter is determined the generations of ants that will go through the TSP instance. As the shortest route to the decision point have more concentrated pheromone leave by the ants through generations, the shortest trail route will become the solution route of TSP form the start point to the decision point as Fig. 1[13].

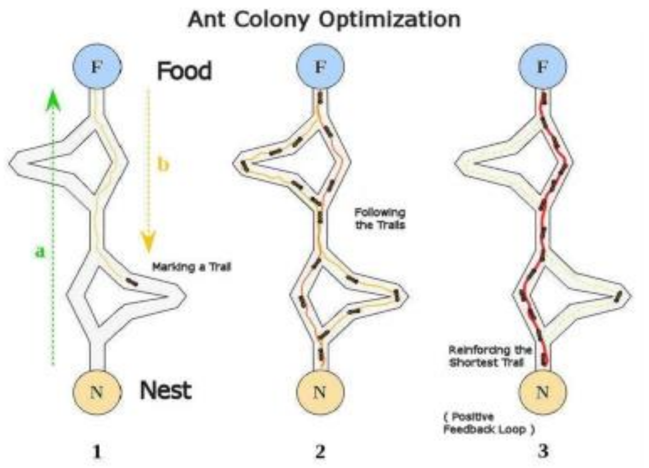

Fig. 1. Formation of solution in ACO algorithm [13]

However, the result of the solution path may affect by the parameters like evaporation rate, pheromone impact and distance impact. As each generation pasted, the pheromone trail will be updated due to the evaporation of the pheromones. An amount of pheromones will be evaporate and affect the route of ACO algorithm.

Moreover, the alpha and beta parameters which are pheromone impact and distance impact will be implemented in the general formula of probability of artificial ants' decision choice as (1) [14]. The pheromone impact parameter is indicated as the parameter which controlled the piping choice of the ants through the relative pheromone. The distance impact parameter is the parameter which controlled the heuristic factor of the piping choice of ants.

$$p_{i(j)}(k) = \frac{[\tau_{i(j)}(k)]^{\alpha} \cdot [\eta_{i(j)}]^{\beta}}{\sum_{l_{i(j)}} [\tau_{i(j)}(k)]^{\alpha} \cdot [\eta_{i(j)}]^{\beta}} \qquad (1)$$

An experiment of parameter tuning on the five parameters stated above is done to find the best value of the parameters in the approach of ACO to solve the TSP. The result of evaluation value will be recorded and being tested for multiple times for average evaluation value to increase the data accuracy of the data collected.

V. Results and Discussion

A. Discussion on Implementation

- Ants per epoch

Ant per epoch is a number of ants to run per generations. Author will test the effect of the parameter by setting different values which is 20, 40, 60, 80, 100. However, the other parameter will remain default which will be Epochs = 100, Evaporation Rate = 0.1, Alpha = 1, Beta = 5.

- Number of epochs

Number of epochs is the number of generations to run. Author will test the effect of the parameter by setting different values which is 20, 40, 60, 80, 100. However, the other parameter will remain default which will be Ants per epoch = 100, Evaporation Rate = 0.1, Alpha = 1, Beta = 5.

- Evaporation rate

Evaporation rate represent how fast the pheromone effects are drying up. The evaporation rate causes the elimination of pheromone trails which cause the ants to be misguided. The author will test the mentioned parameter with different values which are 0.1, 0.3, 0.5, 0.7 and 0.9 while keeping other parameters' value constant.

- Alpha (pheromone impact)

Alpha value represents the impact of pheromones on decision making. The test will be conducted 5 different Alpha values which are 1, 3. 5, 7, and 9. Each Alpha value will be tested 5 times and their average will be recorded.

- Beta (distance impact)

This parameter was being tested which the value of 1,2,3,4,5 and 6 while the other parameters are fixed as the parameter values set in default value where the ants per epoch is set as 100, number of epochs is set as 100, evaporation rate is set as 0.1 and alpha (pheromone impact) is set as 1. There are 5 tests for each value of distance impact parameter and all the evaluation value of the tests for the specific value will be collected and obtain the average evaluation value to increase the accuracy of the result.

B. Results

- Ants per epoch

TABLE I. Result of the experiment on ants per epoch

Ant per epoch	***Evaluation value***	***Average evaluation value***
20	Test 1 : 9999	9834.4
	Test 2 : 9913	
	Test 3 : 9828	
	Test 4 : 9757	
	Test 5 : 9675	
40	Test 1 : 9746	9752.4
	Test 2 : 9635	
	Test 3 : 9668	
	Test 4 : 9907	
	Test 5 : 9806	
60	Test 1 : 9582	9667.2
	Test 2 : 9565	
	Test 3 : 9588	
	Test 4 : 9910	

	Test 5 : 9691	
80	Test 1 : 9539	9522.6
	Test 2 : 9462	
	Test 3 : 9522	
	Test 4 : 9499	
	Test 5 : 9591	
100	Test 1 : 9548	9513.8
	Test 2 : 9651	
	Test 3 : 9726	
	Test 4 : 9340	
	Test 5 : 9304	

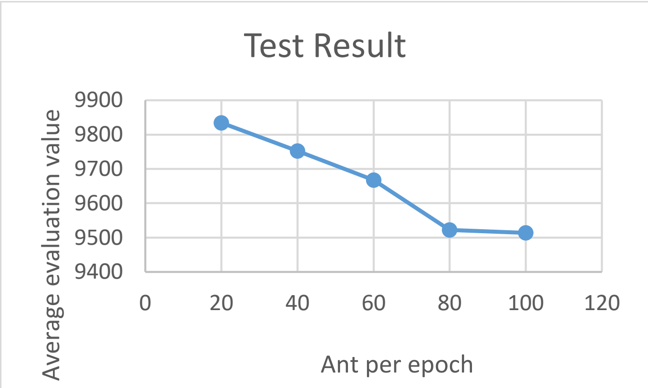

Fig. 2. ANTS per epoch againts evaluation

Based on Fig 2., as the ant per epoch increase the average evaluation value decreases. This shows that the Ant per epoch is indirectly proportional to the average evaluation value. However, we can see that the gap between 80 and 100 is become more slightly difference compared to the previous value. In this case, author assume that there will be a most suitable number of ants per epoch around 100 to 120. More number than 120 may cause the evaluation value increases. It is because the environment isn't infinity large and the population of the ant should not higher than a certain value so that the environment wont overload.

- Number of epochs

TABLE II. RESULT OF THE EXPERIMENT ON NUMBER OF EPOCH

Epochs	Evaluation value	Average evaluation value
20	Test 1: 10097	9992.8
	Test 2: 10042	
	Test 3: 9966	
	Test 4: 9854	
	Test 5: 10005	
40	Test 1: 9519	9624.6
	Test 2: 9731	
	Test 3: 9786	
	Test 4: 9444	
	Test 5: 9643	
60	Test 1: 9489	9537.8
	Test 2: 9516	
	Test 3: 9422	
	Test 4: 9690	
	Test 5: 9572	
80	Test 1: 9561	9466.8
	Test 2: 9510	
	Test 3: 9248	
	Test 4: 9399	
	Test 5: 9616	
100	Test 1: 9442	9510.8
	Test 2: 9522	
	Test 3: 9654	
	Test 4: 9454	
	Test 5: 9482	

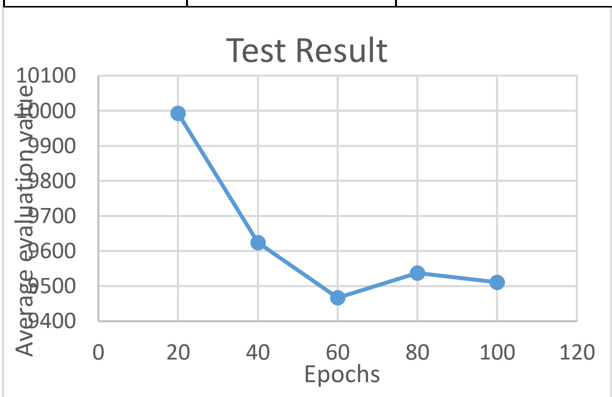

Fig. 3. EPOCHS against evaluation

Based on the line graph produced above, as the epochs increase the average evaluation value decreases. This shows that the Ant per epoch is indirectly proportional to the average evaluation value. However, there is some inconsistency in the graph at the epochs with 60 value shows lowest average evaluation value. In this case, author assume that most suitable number of epochs around 60 will provide the best optimization.

- Evaporation rate

TABLE III. RESULT OF THE EXPERIMENT ON EVAPORATION RATE

Evaporation Rate	Evaluation value	Average evaluation value
0.1	Test 1: 9350	9459.4
	Test 2: 9567	
	Test 3: 9487	
	Test 4: 9367	
	Test 5: 9526	
0.3	Test 1: 9498	9332.8
	Test 2: 9138	
	Test 3: 9305	
	Test 4: 9268	
	Test 5: 9455	
0.5	Test 1: 9683	9488.4
	Test 2: 9493	
	Test 3: 9322	
	Test 4: 9470	
	Test 5: 9474	
0.7	Test 1: 9481	9417.8
	Test 2: 9451	
	Test 3: 9510	
	Test 4: 9383	
	Test 5: 9264	
0.9	Test 1: 9467	9520.6
	Test 2: 9407	
	Test 3: 9488	
	Test 4: 9637	
	Test 5: 9604	

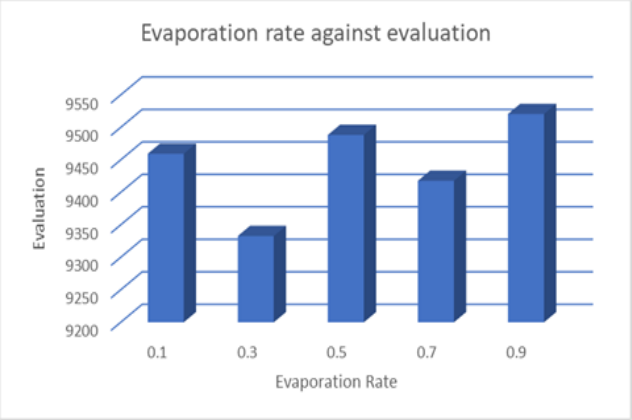

Fig. 4. Evaporation rate against evaluation

Based on the results produced above we can see that as the evaporation rate increase, the evaluation also increases. However, when the evaporation rate at 0.3 and 0.7 there are some inconsistencies found which cannot be taken into consideration. The evaluation value is directly proportional to evaporation rate increases because the more the evaporation rate the faster the pheromone trail to disappear which might lead the ants to be misguided and takes longer time to find the right path again. This shows that the ACO algorithm manage to find the best paths with the lowest evaporation rate.

- Alpha (pheromone impact)

TABLE IV. RESULT OF THE EXPERIMENT ON PHEROMONE IMPACT

Alpha Value	Evaluation value	Average evaluation value
1	Test 1: 9412	9519.4
	Test 2: 9292	
	Test 3: 9639	
	Test 4: 9701	
	Test 5: 9553	
3	Test 1: 9556	9426
	Test 2: 9414	
	Test 3: 9409	
	Test 4: 9182	
	Test 5: 9569	
5	Test 1: 9340	9464.2
	Test 2: 9492	
	Test 3: 9333	
	Test 4: 9564	

	Test 5: 9592	
7	Test 1: 9430	9375.4
	Test 2: 9318	
	Test 3: 9445	
	Test 4: 9338	
	Test 5: 9346	
9	Test 1: 9299	9264
	Test 2: 9366	
	Test 3: 9129	
	Test 4: 9313	
	Test 5: 9213	

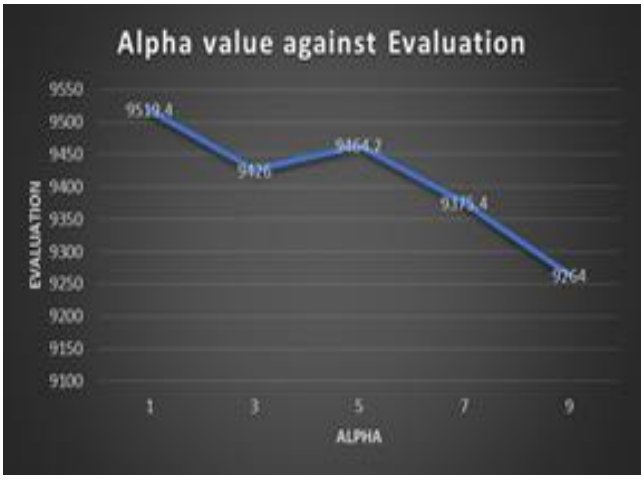

Fig. 5. ALPHA value against evaluation

Based on the line graph produced above, as the Alpha value increase the evaluation decreases. This shows that the Alpha value is indirectly proportional to the evaluation. However, there is some inconsistency in the graph at the alpha value 5 which shows slightly upward gradient. But viewing the graph, we can conclude that ACO finds the best path with the highest alpha value.

- Beta (distance impact)

In the result in Table I, the evaluation value becomes smaller as the distance impact parameter increases. Through the Fig.2, the result of the distance impact parameter from Test 1 to 5 starting from 4 have become stable in the evaluation value between 9000 and 10000. This indicates that the evaluation value starts to reduce in a small value as it may cannot be lower as the evaluation value did not reduce below 9000 This had shown that the optimal route of the TSP instance is around 90000.

TABLE V. RESULT OF THE EXPERIMENT ON DISTANCE IMPACT

Beta (distance impact)	Evaluation value	Average evaluation value
1	Test 1: 14158	14630.8
	Test 2: 14768	
	Test 3: 14677	
	Test 4: 14595	
	Test 5: 14956	
2	Test 1: 11762	11626
	Test 2: 12291	
	Test 3: 11562	
	Test 4: 11107	
	Test 5: 11408	
3	Test 1: 9682	10270.4
	Test 2: 10332	
	Test 3: 10475	
	Test 4: 10696	
	Test 5: 10167	
4	Test 1: 10025	9688.2
	Test 2: 9359	
	Test 3: 9832	
	Test 4: 9448	
	Test 5: 9777	
5	Test 1: 9472	9430
	Test 2: 9397	
	Test 3: 9138	
	Test 4: 9541	
	Test 5: 9602	
6	Test 1: 9281	9370.4
	Test 2: 9467	
	Test 3: 9381	
	Test 4: 9438	
	Test 5: 9285	

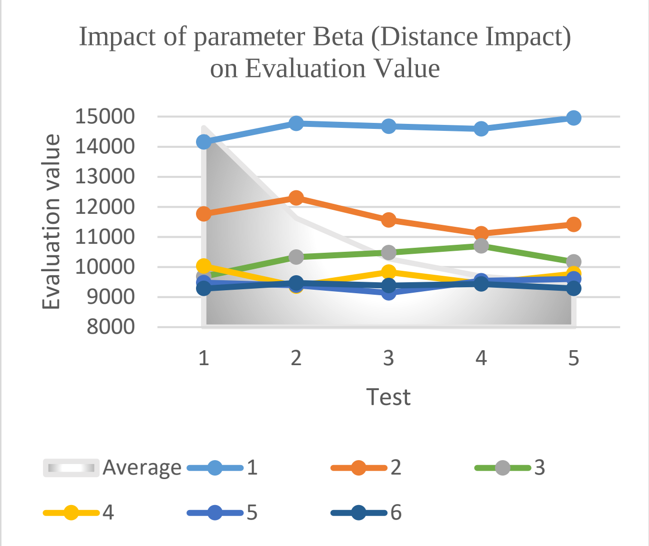

Fig. 6. Line graph of distance impact parameter on evaluation value

Besides that, the distance impact parameter which is value of 5 has the lowest result of evaluation value which is 9138 in test 3. It had also always in the optimal evaluation value of 9000 to 10000. This proved that the parameter of distance impact which value of 5 can get the most optimal route in the parameter interval of <1:6>. Therefore, the ACO algorithm can have a better performance to set the distance impact parameter at 5 so that the optimal route of TSP will be obtained and highest efficiency. This is because as the increment of parameter value, it is meaningless if it did not have big changes on the evaluation value in TSP.

VI. Conclusion

In conclusion, we had observed how the parameters in ACO algorithm affect the performance of finding TSP optimal route and shown the parameter values that is suitable for getting the optimal route. In the TSP for bays29.tsp, the optimal value of parameters is 100 for ants per epoch, 60 for number of epochs, 0.3 for evaporation rate, 9 for pheromones impact and 5 for distance impact so that the performance of ACO algorithm is maximized. There will be more research on analyzing relationships between the parameters in ACO algorithm in the future so that the solutions of TSP can be more optimal and accurate.

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