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Hybrid Metaheuristic Technique Based Tabu Search and Simulated Annealing

Abstract- *This paper presents hybrid technique using two metahueristic methods; which are simulated annealing (SA) and tabu search (TS). The aim is to exhibit the facility of adaptive memory in tabu search method to resolve the long computation times of simulated annealing metaheuristic method. This can be done by keeping the best path which is found in each iteration. As a result, the proposed hybrid technique gives the optimum solution by finding the shortest path with minimum cost when applied on travelling salesman problem (TSP) since it reduces the time complexity by finding the optimum path with a few numbers of iterations when compared with SA and TS.*

Keywords- *Metahueristic, Tabu Search (TS), Simulated Annealing (SA), Optimal Path, Travelling Salesman Problem (TSP).*

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1. Introduction

Optimization problem technique is used to solve any search problem but it cannot give an optimal solution in a reasonable time. This problem can be classified to many types like: continues or separate, restricted or unrestricted, one or multiple-sided, constant or inconstant. Metaheuristic is used to return a good solution for this problem [1].

Metaheuristic is defined as a method of computation that is used to improve problem by attempting to enhance a candidate solution with respect to a particular measure of quality iteratively. Metaheuristics make little or no propositions about the problem being improved and are able to search very big spaces of candidate solutions. Generally, metaheuristics do not guarantee that an optimal solution is found than ever before, but it is guaranteed to find a good solution and the problem cannot stuck at some points.Optimization problems are concentrated on three operators: 1- minimization of the objective function or maximization it. 2- A set of moves which control the objective function. 3- A group of restrictions which allow the moves to exclude some of its values but keep the other values.

The Travelling Salesman Problem (TSP) is defined as an optimization problem which has various applications such as: computer wiring, combinatorial data analysis, vehicle routing and machine scheduling, planning and logistics. These optimization problems can be effectively solved using different techniques that have been proposed [2]. This paper presents a hybrid technique which improves the simulated annealing algorithm by using the adaptive memory of tabu search, which are used to settle the traveling salesman problem (TSP). The TSP concept depends on finding a path for a specified number of cities (visiting all cities only once and returning to the city that started with) where the distance of the path is optimized by finding the shortest path with minimized cost.

2. Related Works

In [2], A.P. Adewole, K. Otubamowo, and T.O. Egunjobi implemented a genetic algorithm and simulated annealing to resolve the TSP. They compared the performance and the results of these two methods and they observed that the quality of genetic algorithm solution is better than simulated annealing, but in terms of runtime they found the genetic algorithm iterations increased with number of cities significantly. So, they proved the simulated annealing runs faster than genetic algorithm.In [3], M. Antosiewicz, G. Koloch and B. Kamiński produced a comparison among six metaheuristic algorithms which are used to solve the travelling salesman problem. They concentrate on genetic algorithms, simulated annealing and tabu search methods, and compared them with the suggested methods represented by the quantum annealing, the particle swarm optimization (PSO) and the harmony search. They evaluated the performance of the algorithms under three measures of criteria which are the quality of the solution, the time it takes to arrive the optimal solution and the standard deviation of the results. The comparison results show that simulated annealing and tabu search are performed better than the suggested methods in shortened simulation run as for the measures of criteria

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(quality, time, and standard deviation). Simulated annealing revealed the better solutions, but the tabu search had lower contrast in results and rapid rapprochements. In [4], P. Azimi, R. Rooeinfar and H. Pourvaziri proposed a hybrid parallel simulated annealing algorithm with a new coding scheme for solving the traveling salesman problem. In the proposed method, various transporting vehicles exist in each city and the type of transporting vehicles sets the cost of travel from city to city. This method has found the optimal route with lower traveling time and cost by using available transporting vehicles, this means, the method has achieved a high speed and good solution quality.

In [5], K. Pandey and P. Jain, applied Genetic algorithm with the tabu search method on sub graph of travelling salesman problem to give the best route without iteration the node and lowers the time complexity for the solution which is reaching it, and the time complexity of the suggested method was better than the genetic algorithm when it applied alone.In [6], A. M. Mohsen integrated the advantages of Ant Colony Optimization (ACO), SA, mutation operator, and local search procedure to create a hybrid method, then applied this method on traveling salesman problem. The diversity of the ant's population was achieved by the ACO, SA and mutation operator, but the local search was used to exploit the current search area efficiently. When he compared the quality of solutions of these methods, he observed the quality solution of the hybrid method is better than the solution of ACO and SA separately, because it consists of fewer distractions ratio.In [7], A. T. Sadiq and A. G. Hamad integrated the characteristics of both the bees algorithm and simulated annealing to present a hybrid technique which solves the NP-complete problems. The aim of integration is to make the hybrid technique has best ability to search and arrive to an optimum solution.

3.Metaheuristic Search

Metaheuristic is an optimization technique begins from the first solution which its quality improved repeatedly through search space depending on a specific quality measure. There are many metaheuristic search techniques that used to settle the optimization problems; this paper uses the simulated annealing and Tabu Search.

Simulated annealing depends on the comparison among solids annealing and settling the optimization problem. Simulated annealing is a probabilistic algorithm, which accepts the good moves and the bad moves with a diminishing probability. The probability of the bad moves is set by two factors: the first one is variation between the values of objective function for current move and the neighbor move, and second factor is the temperature. The purpose of admitting the bad moves is to escape from local minimum [8, 9].

Tabu search retains areas of solutions that have formerly been discovered to avert search within easy reach areas frequently. TS begins from a randomly generated solution, after that it generates a number of neighbors of the current solution and randomly selects any one of them. Tabu search is distinguished from other metaheuristic techniques that has a short term memory or so called tabu list. This memory stores all the generated solutions this helps to avoid re-visiting previously generated solutions, and then averts cycling [10]. TSP is one of the optimization problems that composed of a number of cities; the salesman should visit each city of them only once and come back to the first city that began from it. The solution of the TSP is to find shortest path with minimum cost in reasonable time [11].

I. Simulated Annealing

Simulated Annealing (SA) idea is taken from the process of metallurgy annealing. In this process metallurgy is heated up and cooled it slowly under specific conditions to excess the structure strength of the crystals in the metallurgy and minimize their imperfections. The high temperature maximizes the atoms energy and permitting them free movement; after that, the temperature is cooling down to form a new low energy to be located and utilized [12].Simulated annealing works as follows: From the first solution, SA passes in several iterations. In each iteration, from the current solution a neighbor solution is randomly created. The current solution is swapped by the neighbor solution when the last one is better than the current solution; otherwise, it is swapped with the neighbor solution with a specific probability:

$$\mathrm{Pr} = \exp^{-\Delta \mathrm{Er}/\mathrm{T}} \tag{1}$$

The T and ΔEr are main factors to determine the probabilistic (Pr) value for the neighbor solution, where T represents current temperature; ΔEr represents the subtraction process between the values of the objective function (energy) of current solution (S0) and the neighbor solution (S1):

$$\Delta Er = energy(S_1) - energy(S_0) \tag{2}$$

Simulated Annealing is able to avoid falling into the local minimum. This means the SA does not always refuse changes that reduce or increase the value of objective function [2, 3]. The steps of the simulated annealing are explained in algorithm (1).

The Simulated Annealing Algorithm (1)

Input: Temperature Schedule.
Output: Return the Best Solution.
Process:
S_0= initial solution
Temp = Temp(max); /* initialize the temperature at maximum heat */
Repeat
Repeat /* at current temperature heat */
Select a random solution S_1; /*where S_1 is the neighbor of S_0 */
ΔEr = energy (S_1) − energy (S_0);
If ΔEr ≤ 0 Then
$S_0 = S_1$ /* Replace the previous solution with the neighbor solution */
Else
$Pr = \exp\frac{-\Delta Er}{Temp}$; /* accept the neighbor solution S_1 with a probability as indicated in equation (1)*/
Until Balance Status Satisfied /* according to no. of iterations*/
Temp(new) = update(Temp) /* Temperature is updated by the equation Temp = α * Temp Where α between 0.5 and 0.99.*/
Until Temp(new) ≤ 0 Temp(min) /*stopping condition*/

II. Tabu Search

Tabu search (TS) is one of the most widely applied metaheuristic for solving the TSP. It clearly stores information regarding to the search process, to avoid falling into the local minimum and perform an explorative strategy, represents a major feature of tabu search. Unlike the simulated annealing which does not use memory, so it incapable to learn from the past.The memory which is used by the tabu search algorithm is called the tabu list, which records the solutions recently visited. This list can be viewed as short-term memory which has a specific size. When the list size is small, the search focuses on small areas of the search space. Otherwise, the search focuses on large regions of its space to discover new sets of the solutions.

In tabu search, a neighbor solution is created from the current solution then the two solutions are compared, the best one which has lower value is used to generate another neighbor but the solution which has high value is stored in tabu list. The aim of using tabu list is to avert cycling, so all visited solutions are recorded in tabu list. At each iteration checking if a created solution does not belong to the tabu list.The tabu search algorithm has another feature which is aspiration criteria where tabu solutions can be accepted if the neighbor solution is good but it is tabu, and if it's objective value is better than the current best one, so the criterion is used to cancel tabu [1, 13]. The steps of the tabu search are explained in algorithm (2).

The Tabu Search Algorithm (2)

Input: S_0= initial solution, Tabu memory=0. /*Initialization*/
Output: the best solution
Process:
While not stop do / *Iteration*/
S_1=select best neighbor /*find all possible moves then select the best one*/
Update Tabu Memory
End while
Stop (if the time execution is exceeded, or there are no more possible solutions can be generated then the best solution is found).

٤. The Proposed Work

Algorithm (3) explains the stages of our proposed work as illustrated below:

Hybrid Algorithm (3):

Input: Temperature (Tmp), Tabu length.
Output: Optimal path
Process:
Step 1. Generate an initial solution as a random solution S_0
Step 2. Initialization
Set Tmp=Tmp(max),
Tabu List=0
Step 3. Generate Next Solution
Generate a random neighbor S_1
Compute ΔEr=cost(S_1) - cost(S_0)
If ΔEr≤ 0 then
$S_0 = S_1$ /* Replace the previous solution with the neighbor solution */
Else
Compute $Pr = \exp\frac{-\Delta Er}{Tmp}$
Step4: Tabu List
If S_0 is initial solution then Save S_0 as best solution in tabu list as S_b
Else
If N_s (new neighbor) <S_b then S_b= N_s /*update tabu length list*/
Step 5: Update the Temperature
Tmp(new)= α*Tmp /*in our work , α =0.9 */
Step6: Test the stopping criteria
If Tmp(new)=Tmp(min) then stop
Else go to step 3 to generate new neighbor solution.
Step7: Return the best solution S_b.
End.

The block diagram of our proposed work is shown in figure (1):

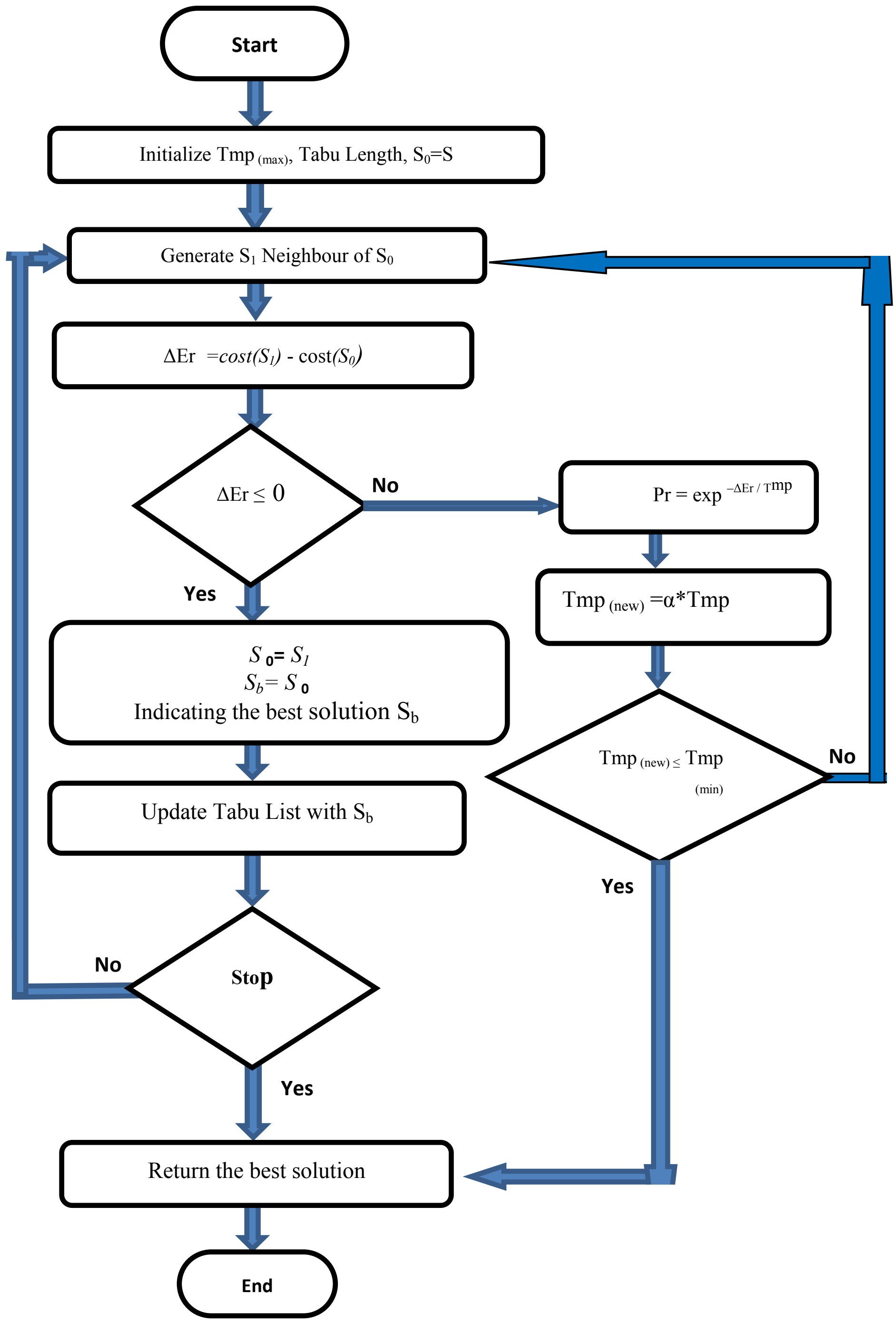

Figure 1: Hybrid Technique Block Diagram

5.Experimental and Results

The experiment and result of our hybrid algorithm is applied on salesman problem with different number of cities (from 10 to 30 cities) as indicated in table (1).

Table 1: Comparison in the no. of iterations between hybrid technique, SA and TS

No. of Cities	Total cost of the Shortest path	No. of Iterations		
		SA	TS	Hybrid
10	320	2	5	1
12	324	10	4	2
14	351	28	9	3
16	354	15	9	4
18	390	90	10	6
20	397	83	12	6
22	413	88	14	13
24	408	74	20	17
26	404	98	23	15
28	416	127	21	19
30	461	116	22	19

The performance of our hybrid technique is compared with SA and TS when 18 cities are used as shown in figure (2), figure (3) and figure (4).

Table (2) shows the comparison between the hybrid technique time complexity with the two other techniques SA and TS, the result proved that our hybrid technique has less time computation than SA and TS.

Table 2: Time complexity in SA, TS, and Hybrid technique by seconds (s)

Time	SA [14]	TS [15]	Hybrid
Seconds	14.2935	1.2231	0.7603

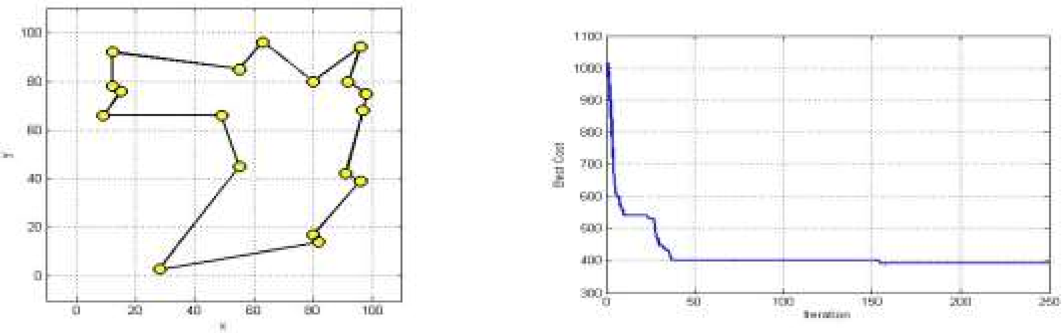

Figure 2: Simulated Annealing (SA)

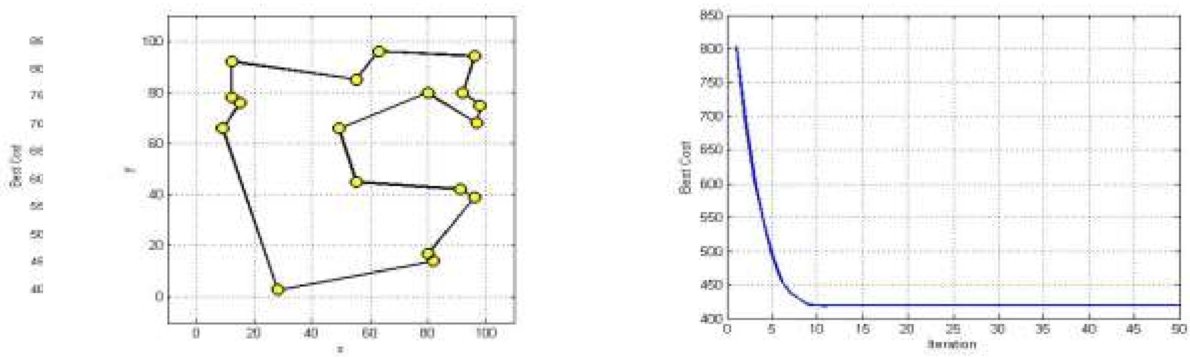

Figure 3: Tabu Search (TS)

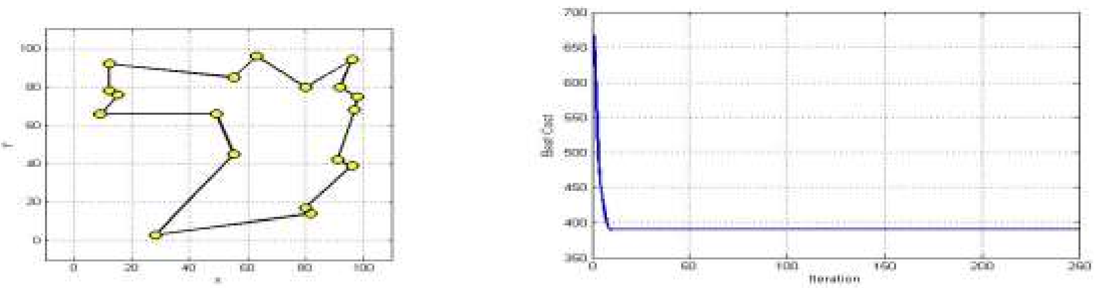

Figure 4: Hybrid Technique

Figure (5) shows the difference between the number of iterations in TS (curve on the left) and Hybrid technique (curve on the left) in finding the shortest path with minimum cost (optimal path) in TSP with 18 cities.

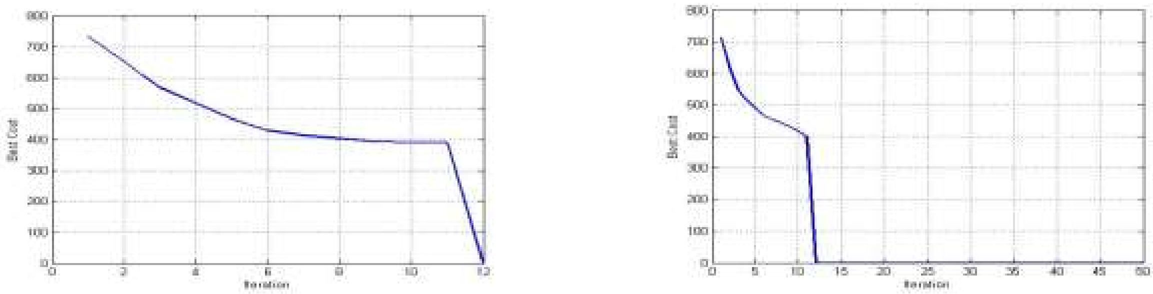

Figure 5: Comparison in finding the optimal path

6. Conclusions

Our hybrid technique is applied to solve salesman problem and is evaluated with different number of cities (10, 12, 14, 16, 18, 20, 22, 24, 26, 28 and 30) cities where the square root is used to find the nearest neighbor between two cities using Euclidean distance and then the shortest distance is selected as the best neighbors. The hybrid technique gives better result than simulated annealing and tabu search methods when they implemented separately. The result shows that the hybrid technique reduced the time complexity by reaching the global optimum faster than SA and TS do, by finding the shortest path with the minimum cost, this is because our technique improves the search by stopping it when it finds the shortest path, in another meaning it take a little number of iterations than the two other methods.

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