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ANALYSIS OF ACO FOR TSP AND VRP USING CBSE METRIC

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Abstract: It is not an easy task to make a new solution every time to solve a complex problem. It is easy to reuse existing solutions and extracts some feature from them and adds some new methodology to create a novel solution. To implement this kind of solution, CBSE concepts may be used. The main factor of CBSE is reusability. Reusability ensures high reliability and efficiency of the system with low maintenance. In this paper, two most popular problems TSP and VRP with ACO has been analyzed using CBSE metrics. Various methodologies and optimization techniques may be applied to solve these types of problem. The working principle and algorithm of these two techniques are also presented in this work. To implement these problems, MATLAB 14.0 is used. The results of both VRP and TSP are compared using a number of iterations and cost. The outcome shows that the best cost value of VRP is high as compare to TSP.

Keywords: CBSE, CBSE Cost Metric, ACO, TSP, VRP.

1. COMPONENT-BASED SOFTWARE ENGINEERING

CBSE is a division of Software Engineering that concern with making software from autonomous functional/logical components. These components have defined interfaces and exchange information through message-passing. In CBSE, the building a software includes a selection of components, reuse the selected components and composition of components rather than making a software from the beginning [1].

The procedure of applying CBSE includes analysis of Component, modification requirements, designing the system with reuse and Development of the system with integrating various components.

2. ANT COLONY OPTIMIZATION (ACO)

It consists of behavioral actions of ants as shown in Figure 1. Ants place pheromone while moving in their path. This path with maximum pheromones is treated as a favorable track that will be followed by other connected ants [2]. The main factors of ACO are ants, pheromones, and cost.

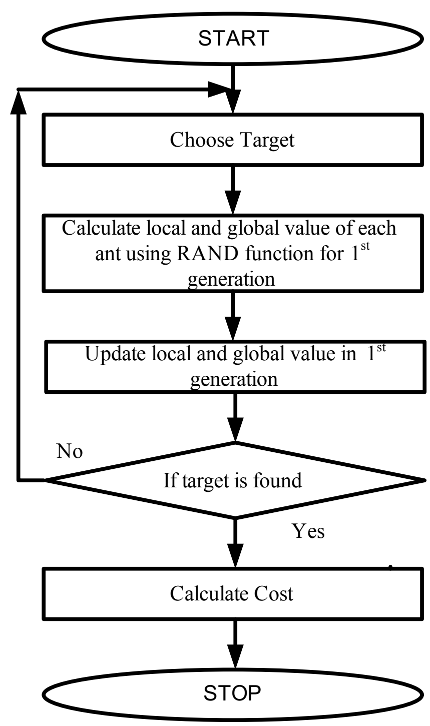

Figure 1: Working of ACO

A. *Applications of ACO:* ACO can be used to solve Scheduling problems, Assignment problems, vehicle routing Problem, TSP, image processing, network model problem etc.

B. *Limitations in ACO:* It is hard to set and find the value of the objective function, decision parameters/constraints for dynamic and stochastic problems. In multiple objectives, it is a complex task to find a quality solution.

3. RELATED WORK

In [3], an improved ACO was proposed that used candidate set strategy and dynamic updating rule performance in solving TSP. The outcome showed better performance as convergence velocity and the ability to finding better solutions than the standard ACO algorithm.

In [4], an algorithm for VRPTW using ACO was presented. A coarse-grained parallelization scheme for ACO is used for better outcomes.

In [5], a model was proposed to solve TSP which includes Ant Colony System (ACS) with memory. The ant's memory is used to accumulate and retrieve information for getting the best solution.

In [6], an algorithm based on usage of Ant System, Elitist Ant System, Max-Min Ant System, Rank based Ant System calculation worry with TSP was actualized in parallel design like GPU to improve the execution and decline execution time.

In [7], a real-life VRP was represented by a seafood product distribution routing problem. The algorithm included a selection of factors α, β, ρ, and crossover rate to enhance the performance of ACO. The testing was performed using benchmark problems of MDVRP.

In [8], an improved ACO based on Ito stochastic process using differential equations was proposed. VRP was analyzed, and then Ito differential equations were integrated with ACO. A modified pheromone rule was given using Brownian motion and optimization rule. The testing was done using Solomon Benchmark standard test dataset.

In [9], an improved ACO with ant-weight approach and mutation process was presented. The computational outcome of 14 benchmark problems presents better effectiveness and efficiency.

In [10], a partitioning technique which was based on divide and conquers approach for TSP was introduced in which the task is split into groups of subproblems. This algorithm may be applied to solve other combinational tasks.

In [11], an approach of ACO to TSP was described. The outcome showed enhanced results with a relatively low number of iterations and getting an optimal solution within relatively short time.

In [12], an approach was proposed that includes a combination of ACO and GA for getting best route. Routing parameters like path length, jitter, and propagation waiting time were obtained for ACO.

In [13], an algorithm was proposed based on ACO and aimed to find a route with least number of vehicles, least time of clients and servers. The algorithm computed initial pheromone cost and visibility function.

In [14], an approach was proposed to solve ambulance direction-finding with ACO. The traveling time based on the distance of path and capacity of sanatoriums. MATLAB was used to implement proposed work. The outcome showed that ACO may be used conveniently for solving VRP.

In [15], a hybrid approach was presented using ACO & GA for VRPTW. This approach provided better outcome when compared to the conventional approach.

In [16], an ACO approach for TSP was proposed to avoid tour loop in Open Vehicle Routing Problem (OVRP). The computed outcome showed: the open route is better when compared to close route for long distance.

In [17], a VRP scheme was presented based on constraints state that was simulated using maximum-minimum ACO with MATLAB. The direction of routing and the minimum amount of vehicles were obtained from simulation outcome.

4. TSP VS. VRP

A. Traveling Salesman Problem (TSP)

TSP focused on finding the distance with a minimum route that begins and finishes at a given node/city and checks every node/city exactly once. The main factors include: set of nodes and distance/cost connecting each couple of nodes.

The type of judgment in TSP is based on routing [3]. TSP is an NP-hard problem. ACO algorithm is applied to analyze the TSP problem. In ACO, ants use direct communication for finding food. Figure 2 shows working with TSP.

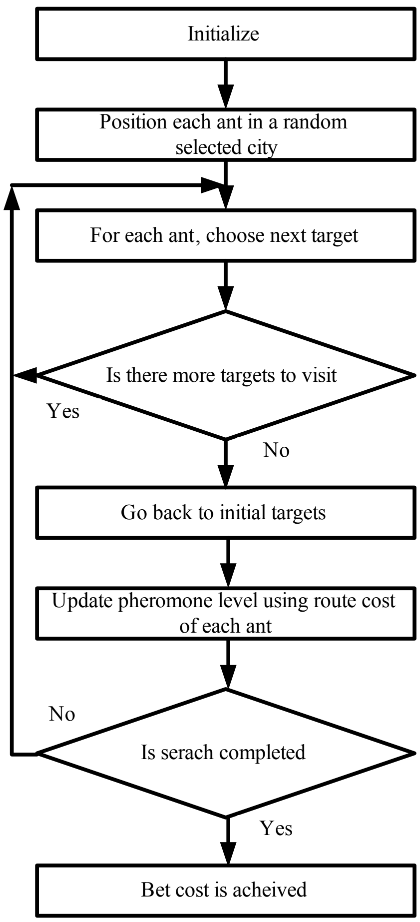

Figure 2: Working of TSP

B. Vehicle Routing Problem

Figure 3 shows working of VRP. VRP is a mixed optimization and integer programming difficulty, the working of which depends on an optimal set of the path for vehicles to traverse the route in a manner to deliver to set of customers. It generalized form of TSP. In the VRP, the individual vehicle has its individual capacity and the individual customer has its own demand. The purpose of VRP is to decrease the overall cost of traveling [4]. The type of judgment in VRP depends on assigning and routing.

C. VRP with Time Windows

It is the variation of VRP that should be finished within a particular time interval. The types of decisions are based on assigning, routing and scheduling. Both VRP and TSP may be represented using the graph with cost assigned to the edges connecting nodes.

The main constraints of VRP include:

- Capacity constraints: the whole demand of customers cannot go beyond the capability of vehicle routes.
- The maximum quantity of nodes/cities that individual vehicle can visit.
- Time constraints: The vehicle has to visit node with time prescribed and with optimal distance coverage.

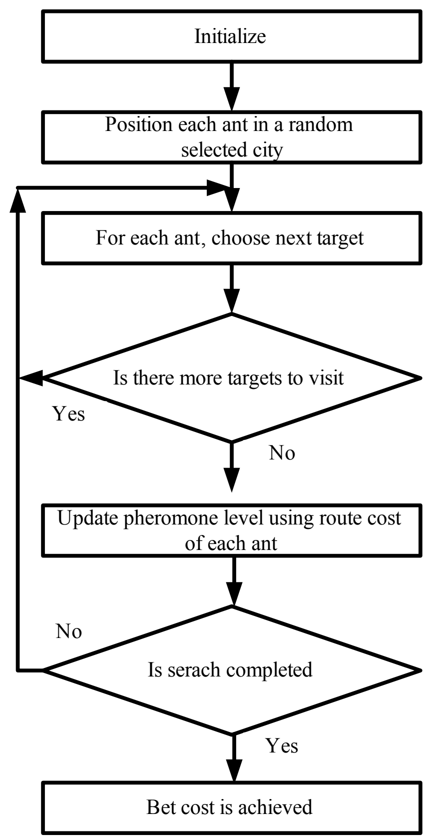

Figure 3: Working of VRP

- Precedence relations: It includes checking of nodes with repeating visiting nodes.

ACO may be applied to analyze VRP because in both the cases, the main objective is to find optimal route among multiple routes.

D. Difference between TSP vs. VRP

Table 1 presents the comparison of TSP and VRP on the basis of their working environment.

Table 1
Comparison the working of TSP and VRP

TSP	*VRP*
The computation of route is in serial form.	The computation of route is in a parallel manner.
It is a complex task to present real-time constraints.	Easy in representing real-time constraints, e.g. total distance and number of vertices by individual vehicles.
The salesman has to visit all nodes and then return back to its starting position.	VRP is to visit a number of locations with a fixed amount of vehicle and minimizes the total travel distance. In standard VRP formulation, all vehicles have equal capacity.
The salesman must return to the starting location after some points have been visited.	This condition is not mandatory in VRP. But acknowledgment is necessary.
It is complex and requires other intermediary reductions.	The reduction from TSP to VRP is instantaneous.

E. Common Constraint

The common constraints of TSP and VRP are time constraints (Overall length of the individual route), precedence relations between nodes and time windows.

5. RESULTS AND ANALYSIS

The work is to analyze ACO for TSP and VRP using CBSE Metric. The various constraints used for implementation of work follow:

A. Tool Used

MATLAB 14.0 is used for the implementation of VRP and TSP problem using ACO. MATLAB is an open source platform for simulation and implementation of various optimization techniques.

B. CBSE Metric Used

Reuse Cost Estimation metric as mentioned in equation 1 is used to calculate the mean cost of the component. Any optimization technique depends on various factors such as iterations, wellness capacity, overall interaction and waiting time between objects. These factors may be utilized to compute the cost of various optimization techniques. The cost is calculated by equation[18]:

$$C_s = C_{nr} - C_r \quad (1)$$

where, C_s is mean/best cost; C_{nr} is developing software with no reuse; C_r is the cost of developing software with reuse. The saving cost C_s can be calculated using a line of code, the function used repeatedly and the function those are not used repeatedly.

Table 2 presents line of code, number of the function used repeatedly and the function those are not used repeatedly. It is necessary to recall a function or statement number of times in a program or module in order to find best cost value. When reusability is applied then duplicates lines are debarred and same statement and functions are reused without complete code.

Table 2
LOC and Function used in TSP and VRP using MATLAB

NP-Hard Problem	*Line of Code*	*Function used repeatedly*	*Function not used repeatedly*	*Optimization Technique Used*
TSP	121	7	3	ACO
VRP	126	9	4	ACO

Table 2 shows parameters used for evaluation of TSP and VRP with the help of reusability metric as shown in equation 1. The number of iteration may be increase or decrease as per analysis requirement.

C. The Outcome of Proposed Work

(i) *Analysis of TSP with ACO:* It uses CBSE metric as metric in equation 1. Figure 4 shows cost value of traveling vs. a number of iterations. The code was executed for a different number of iterations. When the code was executed then few function are reused as shown in table 2.The value of mean cost decreases as an increase in iterations. After some iterations, the cost value decreases constantly.

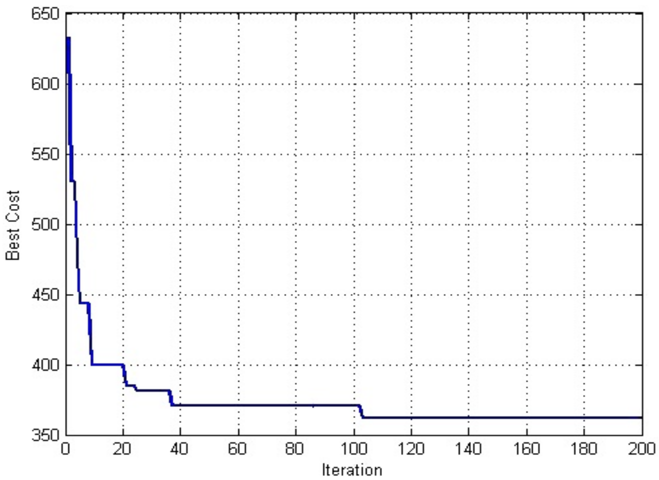

Figure 4: Cost vs. Number of iteration of TSP

(ii) *Analysis of VRP with ACO:* It uses CBSE metric as metric in equation 1.

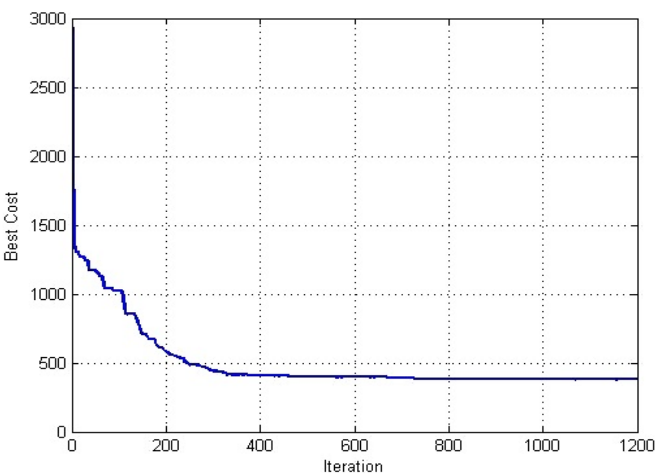

Figure 5: Best cost vs. Number of iterations of VRP

Figure 5 shows cost value of routing vs. number of iterations. The program was executed for a number of iterations. The mean cost value first decreases, and after few iterations, it remains constant.

The best cost exhibits the mean cost as said in reusability metric that is assessed utilizing line of code and capacities utilized as a part of the program for various cycles. The outcome shows that the analysis of VRP with ACO is better as compared to TSP in perspective of mean cost metric.

6. CONCLUSION

It is difficult to solve NP-Hard problems like TSP and VRP. In this paper, ACO has been applied to CBSE cost metric for analyzing of TSP and VRP. The comparison between TSP and VRP has been discussed. The outcome shows that VRP shows better performance as compared to TSP. In future, other optimization techniques may also be applied for analysis of TSP and VRP.

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