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Vehicle Navigation Protocol in Real-Time Fleet Management

R.Kannadasan
School of Computer Science and Engineering
VIT University
Vellore, India

Rohin Sri Kumar
School of Computer Science and Engineering
VIT University
Vellore, India

Keerthan Satya Devineni
School of Computer Science and Engineering
VIT University
Vellore, India

N.Prabakaran
School of Computer Science and Engineering
VIT University
Vellore, India

A.S.Anakath
School of Computing
E.G.S.Pillay Engineering College (Autonomous)
Nagapattinam, India

A.Jayanthiladevi
Computer Science and Information Science
Srinivas University
Bengaluru, India
drjayanthila@ieee.org

***Abstract*- In Real-Time Fleet Management, vehicle routes are built dynamically according to travel durations, location of the vehicles and also customer requests which are revealed gradually. To account for such situations, algorithms which are fast and can accommodate the uncertainty are needed. We here highlights the use of parallel computing strategies for solving real-time vehicle routing problems. The vehicle routing problem is related to linear optimisation and falls under the domain of logistics and transport. Vehicle routing problems comprise of determining optimal vehicle routes according to various constraints such as the total demand should not exceed the total capacity, service durations are met The objectives of solving the Vehicle Routing Protocol varies depending upon the dynamically of the system. In general, systems, which are weakly dynamic, focus on optimising or minimising the routing costs. The systems, which are strongly dynamic, focus more on minimising the expected response time.**

Keywords: Realtime fleet management(RTFM), Vehicle Routing Protocol(VRP), Vehicle Routing Problems(VRPro)

I. INTRODUCTION

The vehicle routing problem is related to linear optimisation and falls under the domain of logistics and transport. Vehicle routing problems comprise of determining optimal vehicle routes according to various constraints such as the total demand should not exceed the total capacity, service durations are met. There are two haul options, long and short. In long haul routing, the vehicles are required to perform a single job whereas in short haul routing, vehicles perform a multitude of jobs. Heuristic and met heuristic approaches have been observed to perform better[1].

The most significant implication of VRP can be seen in what follows-

1) *Couriers:* Couriers which are to be sent long distance are needed to be collected locally. Then the parcels are required to be sent to a remote facility to consolidate loads. Then finally the parcels need to be distributed at the location specified.

2) *Dynamic Fleet Management:* Most large-scale trucking establishments require real-time dispatch of vehicles to collect and/or deliver shipments.

3) *Taxi Services:* In cab services, the requests or the customers are dynamic. Thus, some vehicles remain idle while some are overwhelmed with demand. In such a scenario, relocating idle taxies can help in lowering the workload and optimizing profits.

4) *Emergency Services:* Emergency services are comprised of ambulance service, police and fire fighting services. The demand for emergency is, in general, low which leads to most vehicles being idle. Thus, relocating idle vehicles to areas where anticipated future needs are high is a big issue.

Recent advancements in technology and information gathering like GPS (Global Positioning System), sensors observing traffic flow and GIS (Geographic Information System) have made management of vehicle fleets possible in real-time[2]. The data provided by these sources can be refreshed/updated periodically to dynamically find optimal solutions.

Another development which has helped in the real-time management of fleets is the development of parallel algorithms, the increase in power of hardware equipment and more efficient metaheuristic approaches. The combination of these three can provide real-time solutions in dynamic situation

II. LITERATURE SURVEY

Vehicle Routing Problem is an academic discipline which comprises various managerial, informational and theoretical disciplines. Various algorithmic designs along have been proposed which solve different criticality's of the problem, and yet keep the field open for future enhancements and discoveries in this area. The VRP literature has seen a multitude of applications which have been discussed at length in the past. The applicability and adaptability of the problem to various real-time scenarios makes its importance really high. The first recorded paper in the history of VRP literature was published in by **Dantzig, Fulkerson, and Johnson [1]** which studied a comparatively large Travelling Salesman Problem (TSP) and came up with a solution. Clarke and Wright [2] further went on to add more vehicles to the problem definition. This, therefore, became one of the first recorded instances of the VRP problem.

In **Chiang[3]** a genetic algorithmic approach has been discussed which targets practical scenarios. In non-uniform demand environments where the capacity is influenced by the demand variability, the over and under capacity can be prevented by taking into consideration the correlation between the demand of customers. In **Chen [4]** along with vehicle routes, departure times have also been considered as decision variables. The paper proposes route construction and improvements to develop a coherent method for deciding optimal departure times. Presented as a series of integer programming models it focuses on time-dependent journey periods in a unified environment. **Marta Vallejo [5]** discusses a new memory-based approach for prediction of the optimal routes a prior. Using a clustering representation, the design transforms the VRP into a simplified version of TSP which can easily be solved. When compared with previously proposed genetic and approximative approaches, the proposed solution is more efficient in terms of time and performance. **Gitae Kim [6]** explores the application of VRP in cities also known as City VRP[3]. When compared with the conventional VRP, this model differs when the stakeholders are taken into account. The paper analyses City VRPs based on the problems of interest and focuses on the key issues faced and proposes solutions methods for the same. This includes Modeling methods such as Integer and Mixed Integer Programming, Stochastic Methods and Dynamic Programming whereas the Solution methods include metaheuristics, decomposition, search algorithms, greedy heuristics, and savings heuristics among several others.

In **Hoong Chuin Lau [7]** a variant of VRP has been discussed which is constrained with time windows and a limited number of vehicles. The paper proposes a solution that may consist of either unattended customers or relaxed time windows. An upper bound to the problem has been provided 5 which utilizes a tabu search approach identified by a holding list. The paper introduces the notion lateness and produces solutions close to the proposed upper bound. For the proposed solution as the number of vehicles decreases, the routes go on to become more densely packed. **Sun Zhongyue [8]** has proposed a new solution to bypass the disadvantages of exact and heuristic algorithms with multiple constraints. It discusses a simulation model by combining the discrete event simulation and object-oriented approach. The model has the ability to process various constraints and provide a basis for future optimizations. For practical applications of vehicle routing problem, this method is highly feasible and effective.

In **Sevgi Erdogan [9**] solutions have been formulated to help organizations with alternative fuel powered vehicles to bypass difficulties of limited vehicle driving range and refuelling infrastructure. The paper utilizes two heuristics namely the Density-Based Clustering Algorithm and Modified Clarke and Wright Savings heuristic to improve the performance. It also includes two tour improvement techniques and across tour vertex interchanges. The model can also be extended to account for more complex fuel models and a heterogeneous fleet of vehicles. **Christian [10**] discusses the power of Tabu Search methods over genetic algorithms and VRP with time windows. The proposed algorithm exceeds other tabu search heuristics in terms of the average solution cost by providing a comparatively simple but efficient hybridised genetic algorithm. It is highly efficient when performed on two sets of benchmark instances ranging from 50 to 400 customers.

III. PROBLEM DESCRIPTION

Artificial The Vehicle routing protocol is an integer programming and combinatorial optimisation problem which is like the well-known Travelling salesman problem. The VRP is used to find the optimal solutions or set of routes/paths a vehicle should follow while traversing to deliver to a set of customers. The solution to the VRP is NP-Hard. The main objective of VRP is to is to find the minimal route cost that a vehicle must take while delivering its customers. As mentioned previously that the solution to VRP is NP-Hard, therefore the problem that needs to be solved using the mathematical programming is limited.

Vehicle routing problems comprise of determining optimal vehicle routes according to various constraints such as the total demand should not exceed the total capacity and that the service durations are met. There are two haul options, long and short haul. In the long-haul option, the vehicles are required to perform a single job whereas in the short haul vehicles perform multitude of jobs. The problem is given by initially have a set of N customers (N = {1, 2, .. n}), these n different customers are residing at n different locations. Each of these pairs of locations let's say I and j where i and j belong to N and I is not equal to j is associated with a travel time let's say tij. and a distance travelled dij that are symmetrical to each other Denote by qi , i = 1, 2,..., n the demand at point i . The central depot is denoted by 0.

The customers are served from one depot with a homogeneous and limited fleet. The vehicles leave and return to the depot. There∈ is a set V of vehicles, V = {1,..., m}, with identical capacities. The capacity of each vehicle k V is represented by. The Vehicle Routing protocol can be solved with several algorithms

- Exact approaches
- Constructive method
- Genetic Algorithms
- Tabu search
- 2 – phase algorithms

We to solve the Vehicle routing protocol have used the Tabu search to find the optimal solution. Tabu search is a strategy used to solve the problems based on combinatorial optimization from vast fields varying from graph theory to integer programming problems

IV. SOFTWARE REQUIREMENT

The language that we used to run our code was **Java**. The reason why we used Java for our project is that, recently only Java7 and Java8 have introduced new frameworks on parallelism (Fork Join and stream), the introduction of which have significantly changed the paradigms of parallel programming since the early days of Java. The basic concepts of parallelism like making of the computational graphs, work, span, to find out the ideal parallelism, to see what the maximum speedup is and to see the application of Amdahl's law can be easily seen in Java compared to any other language.

To develop our code in Java we use **NetBeans**. There were several reasons why we used NetBeans over Eclipse to write our code in Java, NetBeans is much easier as compared to Eclipse when it comes to writing the code and following the syntax of the language. In NetBeans there are very few steps that need to be followed as compared to in Eclipse while calling the packages of mpi to introduce parallel programming and it is much easier in NetBeans to perform the steps of Functional Parallelism using the Future and Stream Frameworks and while applying Loop-level parallelism extensions for barrier and iterations grouping. These above-mentioned tasks can be easily done in NetBeans compared to Eclipse and to perform the same tasks in Eclipse a large number of complex steps need to be followed, that is the precise reason why we have used NetBeans over Eclipse for the implementation of VRP.

To implement parallelism in our solution we used the **MPI**, the reason why we used MPI is because MPI can benefit from Java in many ways because of it's widespread and significant applications in the field of HPC. MPI is an API from the HPC library which is used between the communication of the nodes of the system from the distributed memory of the parallel computer.

The various parts of MPI are have been designed in such a way for the fast transfer of data between the various users and nodes of the network and it also helps in supporting the multiple and various modes of message synchronization on the platform of HPC platform.

The higher parts of MPI can be used for the organization, management of the various process groups and threads which helps in providing a collective sense of communication that can be used in a typical parallel application.

There is various feature of MPI that can be incorporated in a application such as N-way communication channel, Single program Multiple Data, and also the use of novel concept of datatypes[4].

MPI has been used in java using the various libraries:-

- JavaMPI
- mpiJAVA
- DOGMA MPIJ
- JMPI
- JavaPVM
- JPVM

The *Hardware requirement* : We are making a project on security for which we have used Java RMI and the system requirement are as follows:

- Intel Corei3
- RAM Size – 256 MB
- Hard Disk – 1 GB

V. MODULE DESCRIPTION

VRP: This class is the main class that, with the help of the rest of the modules/classes computes the minimum cost route by calling various functions of various classes[6]. This is the class that coordinates the running of all other methods and uses various threads for computing the different partial results that are required to complete the entire vehicle routing problem.

Solution : This class is the class that finds the solution of the vehicle routing problem with different parameters using both the Greedy and the Tabu-Search methods and gives the minimum cost route comparing each cost and each method. This module is the core of the entire project as it is the on that finds a solution to the Vehicle Routing Problem and also finds that solution that has the minimum cost associated with it. The Solution module model its solution based on. Various combinations of routes and works in synchrony with vehicle and node modules in order to stay within the constraints of the problem.

Vehicle : This is the module that is used by the Solution class in order to attain the partial mapping of each vehicle's route in order to combine it together into a minimum cost solution. The Vehicle module and the Solution module work in synchrony on order to develop various partial routes and combined routes on various different costs and finally arrive at the one with the minimum cost[7]. This module also is used for implementing a non repetition of the same vehicle and ensuring that only the required number of vehicles are used.

Node: This class is simply used to generate nodes for all the vehicles and the customers that exist in order to make it easier to solve the problem of vehicle routing. Each vehicle is virtually represented as a node and that node is generated by this module. These nodes are then used by the Solution module in order to find the solution to the problem.

draw : This class is simply used to draw or output the final route that is given as the minimum cost route by the Solution module. It draws the path that each vehicle takes in the output and also prints the cost associated with the solution it has drawn. This minimum cost route that is drawn by this module is sent to it by the Solution module[8].

VI. TEST CASE

By modifying the No of Customers and the No of Vehicles to different combinations of numbers, all the various cases of the program can be checked.

CASE 1:

int NoOfCustomers = 20;

int NoOfVehicles = 5;

This test case is the basic case that shows us how 20 customers utilise 5 vehicles that are given to them and the total cost of the route is found out. It also shows us whether or not 5 vehicles are needed for the 20 customers.

CASE 2:

int NoOfCustomers = 30;

int NoOfVehicles = 5;

This test case is the case that builds on the previous case and shows us how 30 customers utilise 5 vehicles that are given to them and the total cost of the route is found out. This case demonstrates to us that if we keep the number of vehicles the same and increase the number of customers, then there is a direct increase in the cost of the route if the number of customers is quite larger than the previous number.

CASE 3:

int NoOfCustomers = 30;

int NoOfVehicles = 10;

This test case is the case that builds on the previous case and shows us how 30 customers utilise 10 vehicles that are given to them and the total cost of the route is found out[9]. This case demonstrates to us that if 30 customers can adequately use 5 vehicles and find the least cost within just the usage of 5 vehicles then even if we provide the 30 customers with more than 5 vehicles(in this case 10 vehicles) then too if the minimum cost can remain the same using the lesser number of vehicles then the additionally provided vehicles will not be used.

CASE 4:

int NoOfCustomers = 20;

int NoOfVehicles = 2;

This test case is the basic case that shows us how what happens if 20 customers are given only 2 vehicles i.e. vehicles lesser in number than the minimum number required for 20 customers to get the least cost path[10]. It shows us whether or not 2 vehicles are adequate for the 20 customers and displays an appropriate message is they are not

VII. RESULT

Execution Case 1

```
Attempting to resolve Vehicle Routing Problem (VRP) for 20 Customers and 5 Vehicles with 50 units of capacity

===========================================================
Solution After TabuSearch

Vehicle 0:0->18->19->1->10->14->6->4->0
Vehicle 1:0->11->16->9->7->17->2->20->0
Vehicle 2:0->5->3->8->12->15->13->0

Solution Cost 590.0
```

Execution Case 2

```
Attempting to resolve Vehicle Routing Problem (VRP) for 30 Customers and 10 Vehicles with 50 units of capacity

===========================================================
Solution After TabuSearch

Vehicle 0:0->18->19->1->10->28->14->15->0
Vehicle 1:0->21->26->11->22->16->25->9->17->0
Vehicle 2:0->6->4->5->3->23->27->24->0
Vehicle 3:0->20->30->8->12->29->13->0
Vehicle 4:0->7->2->0

Solution Cost 793.0
```

Execution Case 3

```
Attempting to resolve Vehicle Routing Problem (VRP) for 30 Customers and 5 Vehicles with 50 units of capacity

===========================================================
Solution After TabuSearch

Vehicle 0:0->18->19->1->10->28->14->15->0
Vehicle 1:0->21->26->11->22->16->25->9->17->0
Vehicle 2:0->6->4->5->3->23->27->24->0
Vehicle 3:0->20->30->8->12->29->13->0
Vehicle 4:0->7->2->0

Solution Cost 793.0
```

Execution Case 4

```
Attempting to resolve Vehicle Routing Problem (VRP) for 20 Customers and 1 Vehicles with 50 units of capacity
Inadequate Number of Vehicles for given Number of Customers, thus minimum cost route cannot be calculated.
```

VIII. CONCLUSION

Vehicle Routing Algorithm is computationally expensive and when implemented in a single processor environment takes more than needed. Since the parallelisation code is faster and gives more accurate results it justifies the motive of the study of parallelising of the code for faster results. In recent times, a lot of literature has been devoted to VRPs. For further scope and advancement in solving VRPs, research work in the future may be directed towards some of the issues presented ahead. One issue that can be looked upon in the future is adding capabilities in heuristics for future predictions to handle current requests optimally not only with respect to current time stamp but in such a way that future demands can also be serviced near-optimally. Routing and dispatching problems pertaining to varying travel durations in real-time can also be looked upon which might help in the development of intelligent transportation systems. VRPs related to emergency services are also a vast area of research as their implications and impacts are global. Finally, automated guided vehicle routing and dispatching problems, which mostly are observed in port terminals and in manufacturing plants, can be addressed.

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