Artificial Intelligence: Vehicle Routing Problem and Multi Agent System

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ABSTRACT

Vehicle Routing problem is present in the world for decades, and some can argue for centuries. Many solutions have been proposed till date with multiple technologies. This problem tries to solve the generation of paths and the assignment of buses on these routes. The objective of this problem is to minimize the number of vehicles required and to maximize the number of demands transported by Multi Agent System with dynamic approach. This paper overviews few approaches with Multi Agent systems, and argues why MAS systems are appropriate for solving VRP's both Static and Dynamic.

1. INTRODUCTION

One of the important group of transportation problems are vehicle routing problems (VRP), where set of customers are to be served by the fleet of capacited vehicles in order to minimize the service cost and satisfying the set of given constraints and transportation demands. And a multi-agent system (MAS,) is a particular sort of distributed systems. The MAS is a system composed of multiple interacting intelligent (autonomous) agents. The paper explains how MAS could be used to solve the Vehicle Routing Problems, dynamically, which are understood as a real time or practical life problems. The paper is covers topics as follows. In Section 2, explains the Vehicle Routing Problem in detail, followed by problem definition and a brief history of solutions proposed in the past decades. Then in Section 3, elaborates MAS, its progress, followed by the argument, how MAS is suitable to solve the VRP in multiple ways.

VEHICLE ROUTING PROBLEM

The Vehicle Routing Problem shares an interesting history, with different variations and forms with respective to time. In the year 1832, a handbook for "Travelling Salesman Problem" (TSP) was found with example tours from Germany to Switzerland, but there were no mathematical calculations in the handbook. Almost after 100 years, in 1930 the TSP first studied by mathematicians during the 1930s in Vienna and at Harvard, notably by Karl Menger. Many researchers claim that VRP is an extension or cousin to the famous and fascinating Travelling Salesman Problem. As the name suggests it is more popular in transportation area. Some common areas where it is an issue are, super markets loading and unloading, courier services, postal services, dial a cab/taxi/ride, emergency services. The objective of these problems is to minimize total cost and/or distance across all routes. For these problem the solutions are in Many areas, routing and scheduling is considered together to solve, but commonly called as vehicle routing problem.

2.1 Problem Definition:

Vehicle routing problem considered to be a classical computer science or operation research category and most of them are NP-hard problems and the problem can be modelled as an undirected graph $G = (V,E)$, where $V = \{0, 1, . . . ,N\}$ is the set of nodes and E is a set of edges. Node 0 is a central depot with NV identical vehicles of capacity W and each other node $i \in V - \{0\}$ denotes customer (with its request) with a non-negative demand di. Each link (i, j) between two customers denotes the shortest path from customer i to j and is described by the cost cij of travel from i to j by shortest path (i, j = 1 . . . ,N) and tij (i, j = 1 . . . ,N) - the travel time for each edge (i, j). It is assumed that cij = cji and tij = tji. The objective is to find vehicle routes such as it minimizes the total cost of travel and/or travel distance in a way that each route starts and ends at the depot at the same time, each customer is serviced only once by a single vehicle, with a

limited capacity of the vehicle. Additionally, it is assumed that certain numbers of customers' requests are available in advance and the remaining requests arrive while the system is already running. In the decade of 80's and 90's number of solutions were introduced with respective to Time, the problems dynamism, etc.. But few solutions really became attractive solutions, such as the probabilistic VRP. Below are the few variants of the VRP's:

• Capacitated Vehicle Routing Problem (CVRP)
• Vehicle Routing Problem with Time Windows (VRPTW)
• Vehicle Routing Problem with Pickup and Delivery (VRPPD)
• Split Delivery Vehicle Routing Problem (SDVRP)
• Stochastic Vehicle Routing Problem (SVRP)
• Site-Dependent Vehicle Routing Problem (SDVRP)
• Arc Routing Problem (ARP)

2. MULTI AGENT SYSTEMS

Multi-Agent Systems, commonly called as MAS are part of Distributed Artificial Intelligence (DAI). One could define MAS in many ways, but in general, an agent could be either hardware of software-based computer system that has the following properties: autonomy, reactivity, pro-activeness, and social ability. In simple words an intelligent agent is a system that behaves autonomously on the behalf of a human being, its behaviour is based on the information given by the owner with the above stated properties and can make its own decision for the owner.

3.1 Why Multi Agents to VRP :

Vehicle Routing can be classified as static or dynamic. If all the input data does not depend on explicitly on time, it is called static else it is dynamic. The problem definition described in the section 2.1 is considered to be a static problem. In simple words, the static routing, is the one in which all information is available before routing algorithm is executed and solution is provided, where new requests are considered as new problem, where as in the dynamic problem, any new request may occur while the system is ready. Hence the current solution to the problem is always reconfigured and updates the set of requests with the entry of new request. The better examples for the dynamic VRP are dial-a-ride systems, and emergency systems. Most of the solutions given in the past decades were suitable to the "Static" VRP. These solutions were not fitting to the raising troubles in the real world. As the industrial society growing larger and wider, the demands of the customers in quality, time and savings increased, resulting into need of developing solutions which can solve dynamic problems. So far classical computer science, Operations research and even centralized AI didn't give an efficient algorithm to cope up with open dynamic routing and scheduling problem. And the real time problems are always dynamic. Hence there raised a need of new technology to understand the complexity and dynamics of the domain. After referring and understanding the problems of implementing the dynamic routing problem, the idea of distributed AI was introduced and explained how it can be useful to use distributed AI for transportation.

Few pragmatic reasons are commonsense knowledge which is necessary to solve the scheduling problems effectively; local knowledge about the capabilities of the Transportation Company as well as knowledge about competitive companies massively influences the solutions. And since global view is impossible due to its complexity, there is a need to deal with incomplete knowledge with all consequences. So this aspect of working with incomplete knowledge leads to the idea of using Multi Agents to solve the problem. As in general, no Agent of the system consists of full information or knowledge about problem. Each agent is programmed or trained to do some part of work, and because of agent's communication property they can easily transfer the required data to each agent and solve the problem faster than static algorithms yet efficiently.

Another important reason behind MAS approach for dynamic problems is that, with the static algorithms, OR algorithms or Centralized AI algorithms the system has to be restarted every time when the plan is modified or adapted. But with MAS approach, it allows for local improvement of tour plans and the handling of inconsistent and fuzzy knowledge, that is why it is flexible in nature and can cope easily with dynamic settings. Now let's have a look at MAS solutions to the VRP, and their progress.

3.2 MAS solutions to VRP:

In section 2.1, we described the general static problem definition of VRP, with the continuation of the below assumptions, it can be used as dynamic problem definition. It is assumed that the planning horizon starts at time 0 and ends at time T . Let ti Є [0, T], where i = 1, . . . ,N denotes the time when the i− th customer request is submitted. Let Ns denotes the number of static (i.e. submitted in advance) requests available in ti = 0, where i = 1, . . . ,Ns and Nd - the number of dynamic requests arriving within the (0, T] interval. Of course Ns + Nd = N. It is easy to see that with each newly arriving dynamic request, the current solution may need to be reconfigured to minimize the total cost of travel. The degree of dynamism of the VRP is represented as below:

$$dod = \frac{N_d}{N_s + N_d}$$

In this, generalized the above definition of degree of dynamism and introduced a new measure of dynamism – an effective degree of dynamism (edod) which takes into account time in which the dynamic requests occur. It is defined as:

$$edod = \frac{\sum_{i=1}^{N}(\frac{t_i}{T})}{N}$$

Suppose edod Є [0, 1] and If edod = 0, then the problem is static, and if edod = 1, the problem is fully dynamic. Such fully dynamic problems will be called on-line VRP. Among the methods for solving Dynamic VRP, the multi-agent approach is very promising and provides trustworthy solutions.

3.2.1 MARS :

One of the first multi agent system developed was for shipping company called Modeling Autonomous CoopeRating Shipping Companies (MARS)[dynamic solving]. MARS was developed to stimulate planning and scheduling dynamically where complete specification of the problem is not available a priori in 1996. The companies (shipping) have to carry out the transportation orders which arrive dynamically. In this approach, the orders are not scheduled by the company but by the trucks used at their disposal. The trucks actually maintain the local plans, actual solution to the global order emerging from the local decision making of the agents. Here a complex plan is replaced by several smaller and simpler plans, allowing reacting quickly and without global re-planning to unforeseen events, such as traffic jams or new transportation orders.

2.2.2 JABAT:

JABAT platform as a middleware along with Multi agents to solve VRP. It produces solutions to combinatorial optimization problems using a set of intelligent optimizing agents, each representing an improvement algorithm. This approach is suggested as JABAT is good for optimization. The main features of JABAT are the following: – The system can in parallel solve instances of several different problems. – A user, having a list of all algorithms implemented for given problem may choose how many and which of them should be used.

The optimization process can be performed on many computers. The user can easily adjoin or delete a computer from the system. In both cases JABAT will adapt to the changes, ommanding the agents working within the system to migrate. The JABAT system is intended as a tool supporting decision making in the field of transportation management. This system offers good quality solutions for the static case, it can also be used a s tool supporting operational decision making. Below is the architecture of the JABAT with Dynamic VRP.

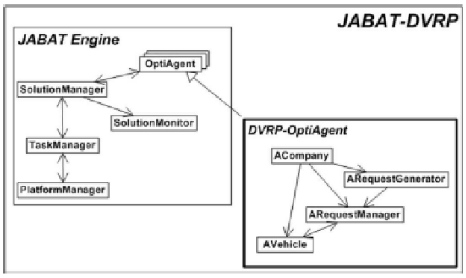

Fig.1 Architecture of the JABAT with Dynamic VRP

Though the system is very good at decision making, the optimization is not upto mark, hence there is always a room for improving the optimization agent, depending upon the current situation of the city, in terms of traffic. The detailed description of static and dynamic VRP with JABAT could be found here.

2.2.3 Ant System:

The ant system is very fascinating as it is derived from the study of real ant colonies. Therefore the system called Ant System (AS) and the algorithms as ant algorithms. This system will have some major differences with a real (natural) one:

• Artificial ants will have some memory,
• They will not be completely blind
• They will live in an environment where time is discrete.

The idea is that if at a given point an ant has to choose among different paths, those which were heavily chosen by preceding ants (that is, those with a high trail level) are chosen with higher probability. Furthermore high trail levels are synonymous with short paths. Even if no tour is completely excluded, bad tours become highly improbable, and the agents search only in the neighbourhood of good solutions.

The actual idea looks as below:

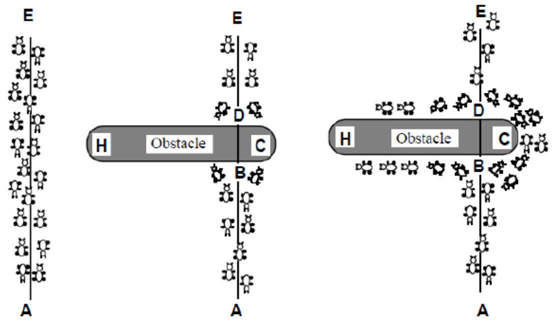

Fig.2 An example with real ants.

a. Ants follow a path between points A and E.
b. An obstacle is interposed, ants can choose to go around if following one of the two different
c. paths with equal probability.
d. On the shorter path more pheromone is laid down

3. CONCLUSIONS

In this paper, we focused on why MAS approach is suitable for solving Vehicle Routing Problem. In the field of Artificial Intelligence, the VRP could be solved in many other ways, such as, Evolutionary Algorithm. Genetic Algorithms under Evolutionary Algorithms also gave numerous solutions, but our concern here is not to compare with any other technology. We strictly talked about only MAS approach. More technologies in MAS for VRP could be found here. In future, the developments might take place without drivers in the vehicles. One can argue that VRP without Drivers in the vehicles could be dangerous as a machine cannot follow the traffic lights and other cars in comparison to a human being. But there is always a room for experiments and developments.

4. REFERENCES

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