A Candidate List Extension for Ant Colony System Solution of the VRP with Time Windows

Juan Javier Gonzales Barbosa, Claudia Gomez Santillan, Laura Cruz Reyes, Hector Joaquin Fraire Huacuja, Rodolfo A. Pazos R., Jose Ricardo Camara Covarrubias, Juan Arturo Herrera Ortiz

Instituto Tecnologico de Ciudad Madero (ITCM), Av. 1o. de Mayo esq. Sor Juana Ines de la Cruz s/n Col. Los Mangos C.P.89440, Cd. Madero Tamaulipas, Mexico.
jjgonzalezbarbosa@hotmail.com, cgg71@hotmail.com, lauracruzreyes@hotmail.com, automatas2002@yahoo.com.mx, josericardocc@gmail.com

Extended Abstract

1 Abstract.

In this paper the solution of the Vehicle Routing Problem with Time Windows (VRPTW) using the Ant Colony System (ACS) is approached. A state-of-the-art implementation of ACS uses a candidate list to incorporate geographic information of the customers. We propose a new candidate list extension to include information of the length of the time windows, for identifying those clients with a small length of time window in order to give them a larger visit priority when the ants search for a new solution. To validate the benefit of this strategy, a series of computational experiments were conducted with the use of the standard Solomon's Benchmark. The results show that the proposed strategy is able to reduce by a 2.82% the average number of vehicles used for the Solomon non clustered instances.

2 Introduction.

Vehicle Routing Problem (VRP) is a well-known hard combinatorial problem, which has received considerable attention in recent years for its applications in transportation logistics in real life [5], [7], [4], [1], [6]. The objective of the VRP is to find optimal tours from a central depot to a set of know clients, using the least numbers of vehicles with known capacities to satisfy customer demands. VRPTW is a variant of VRP where additionally each vehicle must meet the time windows of the costumers, which specify the earliest and latest times for the start of service at a customer site. A vehicle is permitted to arrive before the opening of the time windows, and wait at no cost until service becomes possible, but it is not permitted to arrive after the closing time of the window. A state-of-the-art implementation of Ant Colony System (ACS) to solve VRPTW uses a candidate list to incorporate geographic information of the customers [2] [3]. We propose a new candidate list extension to include information of the length of the time windows, for identifying those clients with a short length of time window in order to give them a larger visit priority when the ants search for a new solution.

3 Analysis of Solomon Instances

In the VRPTW context, the most common way to compare the performance of heuristic algorithms is solving the instances of the Solomons benchmark [8]. These instance problems include a variety of clients, a central depot, capacity constraints, demand constraints and time window distributions. The Solomon data set consists of 6 different classes: R1, C1, RC1, R2, C2, and RC2. Each class contains between 8 and 12 instances of 100 customers, where the first customer represents the depot, and the rest constitutes a set of distributed clients to visit in a service area defined in a 100x100 grid. Travel times and distances between nodes are defined using the Euclidean distance. Each class is divided by taking into account the Cartesian coordinates of the clients. This information is denoted by its prefix, defining 3 types of instances according to their topology. Table 1, provides a brief description of each type.

Table 1: Classification of Solomon instances by their prefix

Prefix	Description
C	The clients are distributed by clusters
R	The clients are randomly generated with a uniform distribution
RC	The clients are semi-clustered (i.e., a combination of both clustered and randomly distributed)

All the instances of a particular class have the same customer locations and the same vehicle capacities, but the client's time windows constraints differ in each instance. In addition to the prefix there is another classification according to their postfix as described in Table 2.

Table 2: Classification of Solomon instances by their postfix [8]

Postfix	Description
1	Tight time windows and short scheduling horizons
2	Wide time windows and long scheduling horizons

In this paper, we show that another sub classification can be identified that provides additional information that helps to characterize the instances. By analyzing the length of time windows, the difference between the start time and end time for each client, we defined a new classification. The distribution of the length of time window $D(i)$ is a function that describes the duration of the time windows for a client i (Equation 1). Formally,

$$D(i) = X^i_{(b_i - e_i)} \tag{1}$$

where i is a client in the set of clients N, b_i is the start time of the window for client i and e_i is the end time of the client i. A graph of $D(i)$ can be seen as a histogram showing the behavior of the time windows for the clients involved in a particular instance. Depending on this distribution the instances are classified according to their time length for a given instance. In the distribution of the size of time windows, it was found that it is possible to further characterize the behavior of the customer time windows in a given Solomon instance. We identified 3 types of distributions based on the shape of the graph: linear, curved and phased.

3.1 Linear distribution for the size of the time windows

In Figure 1 we show an example of linear distribution, where the length of the time windows is constant for all the clients in the instance. We found that there were 12 instances out of the entire set of 56, which have a linear distribution; this represents approximately 21% of the total.

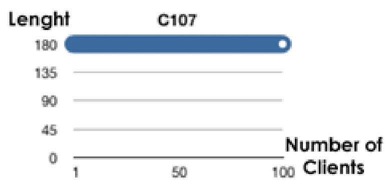

Figure 1: Example of linear distribution behavior for instance C107.

3.2 Curved distribution for the size of the time windows

We defined curved behavior where clients have uniform differences in length from each other in a certain instance as can be seen in Figure 2. We found that 33% of the instances show a curved behavior for the distribution of time windows.

3.3 Phased distribution for the size of the time windows

In Figure 3 we present an example for phased distribution for the size of time windows. We found that phased distribution occurs in 26 instances out of the total of 56; this constitutes 46% for the total instances in the Solomon set [8]. In the graph of phased distribution two groups of clients are clearly discerned,, those who

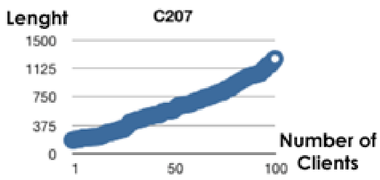

Figure 2: Example of curved distribution behavior for instance C207.

have a small size of time window and those that have large size of time window. A particular feature in this type of distribution is the percentage of customers who have larger length (conversely small size), which can represent 25%, 50% or 75% of the total clients.

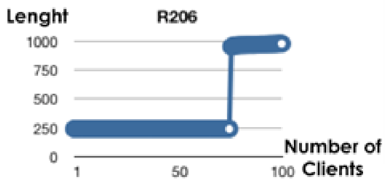

Figure 3: Example of phased distribution for instance R206 that has 25% of clients with large size of time window.

The most interesting structure of the instances is the phased distribution that constitudes about 50% of the instances in the Solomon benchmark. Since this distribution makes the distinction between two groups of clients (those with short length and long length), is convenient to use this information to improve the ACS-VRPTW algorithm. In the next sections we propose a strategy that uses this information in order to guide the ants towards better solutions.

4 Candidate List Extension (CLE) for ACS-VRPTW

The use of a candidate list (CL) proposed by Dorigo when applied to the ACS-VRPTW algorithm has shown an improvement in the solution on the Solomon instances [2],[4]. However, it's noteworthy that this strategy is only useful when the client's locations are in clusters. A major weakness of the strategy occurs when it is applied to instances whose clients in the geographical space are not grouped, therefore, the clients are classified as one group and don't generate any additional information to the ant to help find better solutions. The candidate list makes use of the information of the topology of the clients in the instance. We found that it is convenient to include also the client's time window size. With this information we developed an extension of the candidate list. The objective of this new strategy is to identify those clients that have a short length of time window when the distribution of the time window has a phased form. When the instance is recognized as having a phased distribution, a classification of its clients is carried out by detecting those clients with a short length of time window in order to give them a larger visit priority when the ants perform a search for a new solution.

5 Computational Results

The computational experiments were done on a computer with an Intel Xeon 5120 with 2 cores at 1.86 GHz with 3.0 GB of RAM. The OS was Windows XP Service Pack 3 32bits, with the IDE of Microsoft Visual C# Express 2010. The parameter values used were n = 10 for artificial ants and α = 1, $q0$ = 0.65, β = 6 y p= 0.1. The stopping condition was 1800 seconds for each Solomon instance [8].

The main goal for real applications of VRPTW is to minimize the number of required vehicles. Therefore, we carried out a series of experiments to solve the the Solomon's instances. Table 3 contains the results obtained in this experiments for all the instance sets (C1, C2, R1, R2, RC1, RC2). As we can see, the ACS with CL and CLE shows the same performance for the clustered instances (C1, C2, RC1 and RC2). In another hand, ACS with CLE clearly outperforms to the ACS with CL for the non clustered instances (R1, R2), because it reduces (2.82%) the average number of vehicles. As we can see, in this case the ants built better solutions by ignoring the clients with larger time windows in order to reach those clients with shorter time windows.

Table 3: Average number of vehicles determined by ACS-VRPTW algorithm with the use of the candidate list extension (CLE) and the candidate list (CL) used in [4].

	C1	C2	R1	R2	RC1	RC2
CL	10	3	12.8	3.15	12.1	3.3
CLE	10	3	12.5	3	12.1	3.3

6 Conclusions

In this work the solution of the Vehicle Routing Problem with Time Windows (VRPTW) using the Ant Colony System (ACS) is approached. A state-of-the-art implementation of ACS uses a candidate list to incorporate geographic information of the customers. We propose a new candidate list extension to include information of the length of the time windows, for identifying those clients with a small length of time window in order to give them a larger visit priority when the ants search for a new solution. The computational results show that the proposed strategy is able to reduce a 2.82% the average number of vehicles used for the Solomon's non clustered instances.

We are now currently applying this strategy to improve the performance of other heuristic algorithms for VRPTW.

References

[1] Cruz, B.A.A.: Bsqueda local mejorada para la solucin del problema vrptw en un sistema de colonia de hormigas. Master's thesis, Instituto Tecnolgico de Cuidad Madero, Mxico (2007)

[2] Dorigo, M., Gambardella, L.M.: Ant colony system: A cooperative learning approach to the traveling salesman problem(doi:10.1109/4235.585892). IEEE Transactions on Evolutionary Computation **1**(1), 53–66 (1997)

[3] Gambardella, L.M., Dorigo, M.: An ant colony system hybridized with a new local search for the sequential ordering problem (2000)

[4] Herrera-Ortiz, J.A.: Desarrollo de una metodologa basada en heursticas para la solucin integral integral de problemas de asignacin de rutas, horarios y cargas en el proceso de distribucin y entrega de productos. Master's thesis, Instituto Tecnolgico de Cuidad Madero, Mxico (2006)

[5] Koskosidis, I.A., Powell, W., Solomon, M.: An optimization-based heuristic for vehicle routing and scheduling with soft time window constraints. Transportation Science **26**(2), 69–85 (1992)

[6] Montemanni, R., Gambardella, L., Rizzoli, A.E., Donati, A.V.: A new algorithm for a dynamic vehicle routing problem based on ant colony system. In: In Second International Workshop on Freight Transportation and Logistics, pp. 27–30 (2003)

[7] Rangel-Valdez, N.: Anlisis de los problemas de asignacin de rutas, horarios y cargas en una distribuidora de productos. Master's thesis, Instituto Tecnolgico de Cuidad Madero, Mxico (2005)

[8] Solomon, M.M., Solomon, M.M.: Algorithms for the vehicle routing and scheduling problems with time window constraints. Operations Research **35**, 254–265 (1987)