Ant Colony Optimization for an Adaptive Transportation System: A New Termination Condition Definition Using an Environment Based Approach

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Resume of Presenter

Pierre ROMET

Engineer specializes in embedded software.

Currently PhD student at CIAD laboratory.

The laboratory is under the supervision of the University of Burgundy and the supervision of the University of Technology of Belfort-Montbéliard.

Currently working on transport system optimization and autonomous vehicle.

Our team is searching to develop an adaptive transportation system based on electric autonomous vehicle, in order to consider customers (and its unpredictable behavior) as the main issues of the system. Furthermore, with autonomous vehicle, we search to minimize their impact on the city center traffic.

Urban and General Traffic Issues

Currently, the road city transport system is more and more overloaded by an increasing number of vehicles, for personal use, delivery of goods or public transport system.
Thus, city centers are faced with :

Adaptability of vehicle to the context and to their real use case.
In 2011, delivery of goods reaches 20% of the global urban daily traffic in big cities.

Congestion
&
traffic jam

In 2012, a study in the Strasbourg agglomeration noticed that the 233.000 weekly travels due to the transport of goods produced 34.000 tons of CO2.

Delivery of Goods vs. Public Transportation Systems : Similarities and Differences

Similar:
- Same side effects (pollution, traffic jam,…)
- Require new adapted incitation / restriction rules
- Requires improvements on both system and vehicle sides

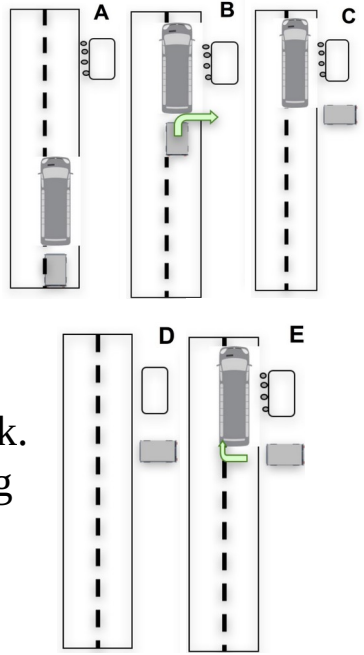
Different:
- Few possible actions at individual level
- Must face to an increase of e-platform business with a spreading in time and space hardly predictable.
- The driver’s social and safety conditions (time schedule pressure…)

Thus, the pooling of the goods transportation system and the public transport system appear to be a good solution to minimize the impact on both systems on the city center traffic. Furthermore, replace inadequate big delivery vehicle by smaller autonomous electric vehicle that use platoon behavior to move on public transportation system, behind the bus offer to decrease the traffic jam and the pollution in the city center.

How can we apply platoon control to the delivery of goods in urban areas?

Principles:

- Delivering goods to small commercial areas in inner city centers.
- Small electrical vehicles able to hang to other vehicles, whatever their type.
- The vehicle can be loaded with specific exchange points (such as Urban Distribution Centers) and then use the existing public transportation system network to perform its task.
- A delivery system that can « take the bus » using platoon abilities and deliver goods as close as possible to the final targets (near bus stops)



- The system is using an already existing transportation network
- No need to introduce a new transportation network avoiding a shift of the traffic jam from the main pathways to the secondary roads.
- Few impacts on the existing public transportation system.
- The system can adapt to the demand through time and space.
- It can be a solution for introducing additional services.

Metaheuristics Graph Based Approach

Graph based representation :
The delivery of goods is a classic application in the field of system optimization. Based on this, city point delivery can be seen as a vertex, that need to be linked together with edges (the road) in the graph. Thus, its representation in graph form appears as the most appropriate way to deal with this problem.

Ant colony optimization :
Our application considers customers as the backbones of the system. Thus, according to customers adaptive possibility to be present to pick up his good(s), the graph needs to be able to keep tracks of already visited city points delivery and paths that connect them.
To answer this problem, the ant colony algorithm appears to be the right answer. Thanks to its pheromone traces, we do not need to recalculate the whole graph to find new solutions to return to already visited city point delivery, to adapt to the presence of customers.

Objectives

Optimization

Based on the Ant Colony to perform on the VRP algorithm, thanks to its intrinsic ability of adaptation to the dynamic update of the graph.

The following research focus on the possibility to improve this algorithm by offer it an adaptive termination criterion, to dynamically end the algorithm iteration.

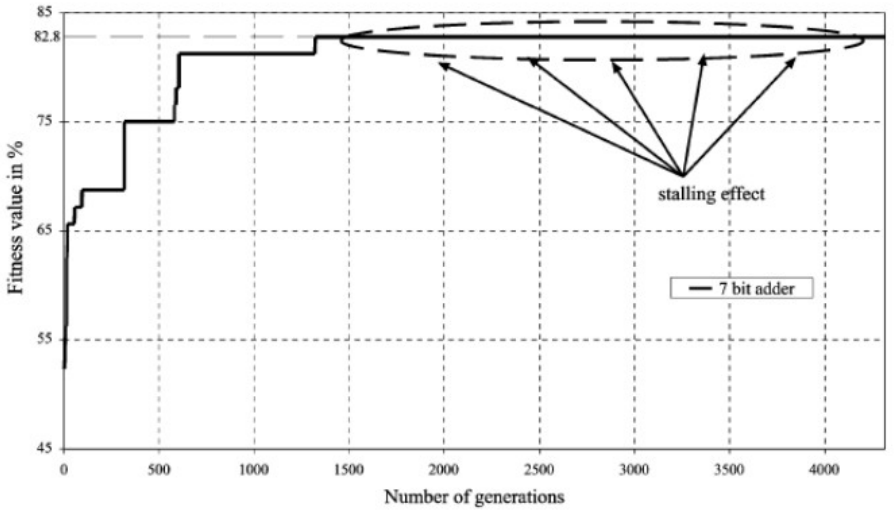
Transportation System

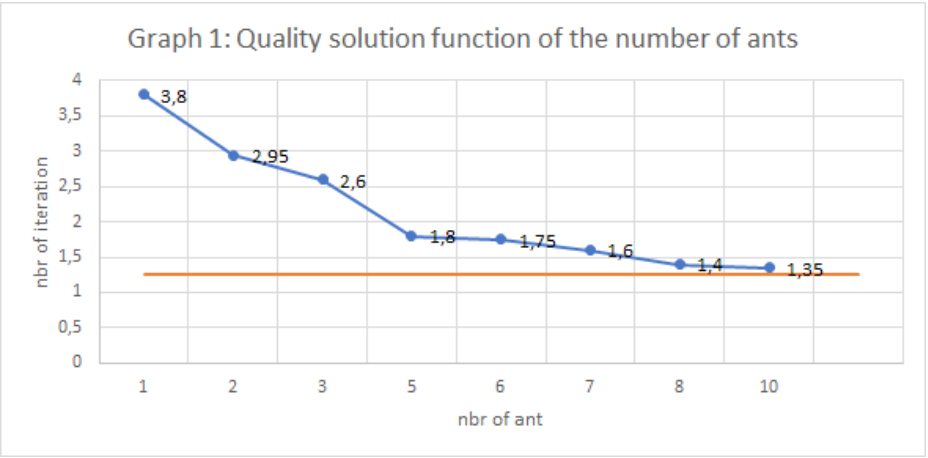
Based on our electric autonomous platoon transportation system, we want to consider the unpredictable behavior of the customer to be present to get its packages by dynamically adapt the turn and do not impact the next turn.

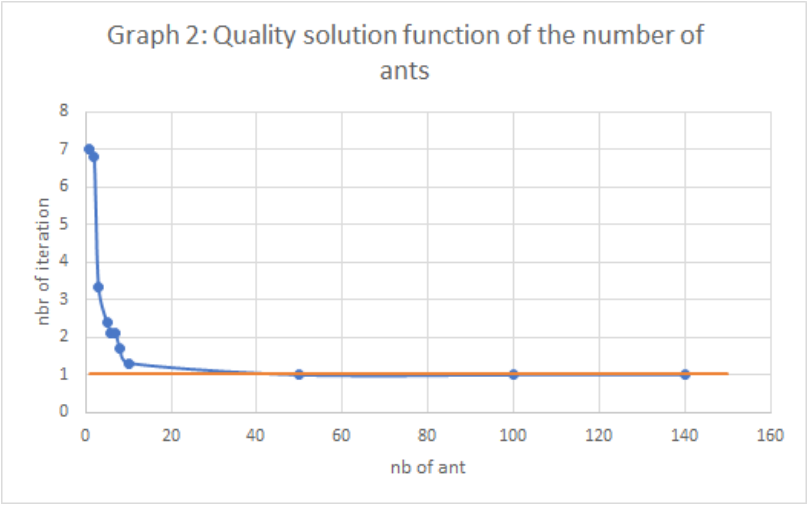
Environment Based Approach for the Ant Colony Convergence

The ant colony optimization is characterized by a stochastic behavior to solve optimization problem. However, although the algorithm dynamically converge on a solution, the termination criterion of the algorithm remains arbitrarily defined by the scientist.

Thus, we are searching to identify how to provide an adaptive termination criterion, to have a fully dynamic Ant Colony Algorithm.







According to this problem, we offer to search if an environment based approach can be the key to determine an adaptive termination criterian.

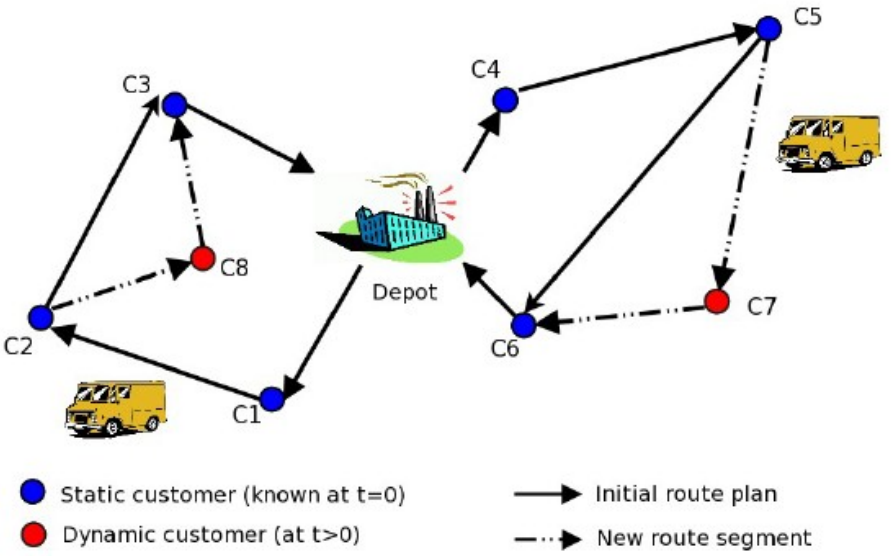
Thus, we want to correlate the optimal number of ants (based on Dorigo research) with the needed number of iterations to solve the problem.
In addition, we compare this value with the average number of edges connecting a vertex to others in the graph (this is the environment based approach).

We can observe that those approaches converge to the same value. Allowing to conclude that an environment based approach is the key to provide an adaptive termination criterion.

Adaptive Transportation System at Delivery Point

Searching to develop an adaptive transportation system, to adapt to the unpredictable behavior of the customers. The objective was to adapt functionnal(s) solution(s) to fit this problematic.

Thus, by coupling classical VRP application with shortest path and a reverse list of visits city point, we want to offer a solution that can deliver all its packages in one turn, but with an optimized total travel distance in accordance with the use of electric vehicles.



Strategies	total distance (km)	total time (min)
Strategy 1	44	29
Strat2: frst variant cascading VRP	52	114
VRP and ShP	49	110
Strat2: scd variant cascading VRP	44	102
VRP and ShP	41	98
VRP = Vehicle Routing Problem, ShP = Shorstest Path		

According to this paradigm, we developped two different strategies that we compared with a classical VRP algorithm.

Even if the time indicator is clearly deteriorated compared to classical VRP, the total distance travel appeared to be improved compared to classical VRP.

Thus, this improvement of total distance indicator supports the use of electric vehicles for future research.

Conclusion & Futur Work

Optimization :
Concerning ant colony optimization, we provide a new adaptive termination criterion, which confers a fully dynamic behavior to the ant colony algorithm.

Transportation system :
Concerning transportation system, thanks to the adaptation of classical optimization approach, we provide an algorithm allowing to deliver all packages in one turn, by adapting to the unpredictable behavior of customers.

Futur Work :
According to this result, the next step will be to introduce electric vehicle in this transportation system.

Using electric vehicle, the objective will be to analyse the battery status during a turn to identify different strategies to maximize the vehicle battery life.

Finnaly, after this, we will introduce electric autonomous vehicle in the transportation system.