Truck Dispatch Scheduling by Constraint Logic Programming

Shoichi Hatori

System Plaza Inc., Supply Chain Division (shoichi.hatori@systemplaza.co.jp)

Abstract

Constraint logic programming is helpful to solve combinatorial problems with many constraints in a short time. A truck dispatch scheduling is a kind of these problems, and constraint logic programming is applied to this problem.

As the first example, a petroleum tank truck dispatch scheduling is shown. Every delivery order has oil types and quantities, and most orders have other miscellaneous conditions, such as the delivery time bucket. These order conditions combine the shipping point conditions, delivery point conditions, truck conditions, and transportation conditions. These conditions and their combinations are constraints. The objective is to minimize the total cost including shipping costs and transportation costs.

All delivery orders should be allocated to the trucks that can be used that day, and all constraints should be satisfied. The optimal solution cannot be obtained in daily acceptable time length even by using constraint logic programming, and the calculation is ended on the initially given time length. The best solution among the obtained ones, is adopted as the realistically best solution. Not perfect but acceptable results are usually obtained. In the case that small modifications are necessary, the automatically obtained results are manually modified.

Constraint logic programming is also applied to another type of truck dispatch scheduling, such as paper product transporting trucks. Many constraints of paper product transporting trucks are similar to those of petroleum tank trucks, but the difference between solid and liquid is big. Volume and weight should be checked for petroleum tank trucks, and in addition shapes and sizes should be checked for paper product transporting trucks.

1. Introduction

Truck dispatch scheduling is a kind of combinatorial problems, and so MIP, expert system, genetic algorithm, and many other OR or AI methods are applicable to this problem.

However, it is difficult to obtain solutions that satisfy all constraints because of too many constraints. This difficulty sometimes causes many manual modifications, and there are complaints that the effect of auto-scheduling is small. In addition, there is a complaint that some stochastic methods cannot reproduce the solution and cannot be used for case studies.

On the other hand, it is known that constraint logic programming solves combinatorial problems with many constraints in a short time and reproduce the solution with the same input. However, many successful examples using constraint logic programming are not reported.

Under the above background, constraint logic programming has been applied to truck dispatch scheduling, and good results have been obtained.

2. First example : tank trucks for petroleum products

2.1 Transportation of petroleum

Transportation routes of petroleum are shown in Fig.1. Crude oil is transported from petroleum producing district to a refinery, and is separated into petroleum products such as gasoline, kerosene, and heavy oil. These petroleum products are transported from the refinery directly or via oil terminals to gas stations or big users.

Petroleum products are usually transported from refineries and oil terminals (shipping points) to gas stations and big users (delivery points) by tank trucks.

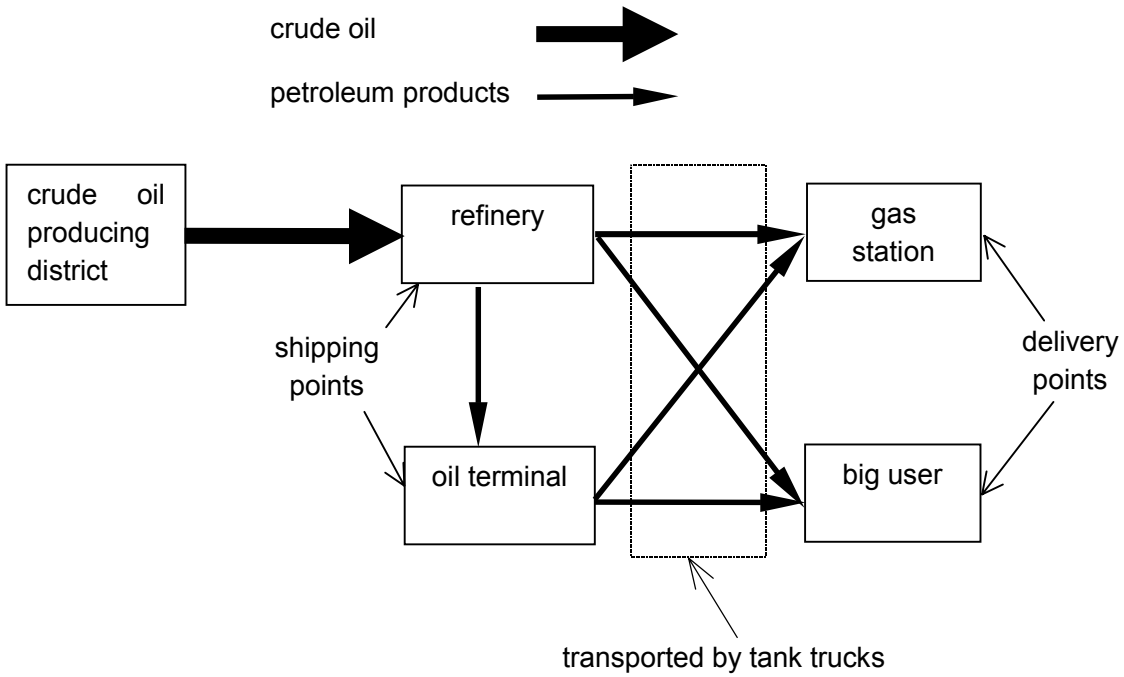

Fig 1. Transportation routes of petroleum

2.2 Transportation by tank trucks

An example of one-day run of one truck is shown in Fig. 2.

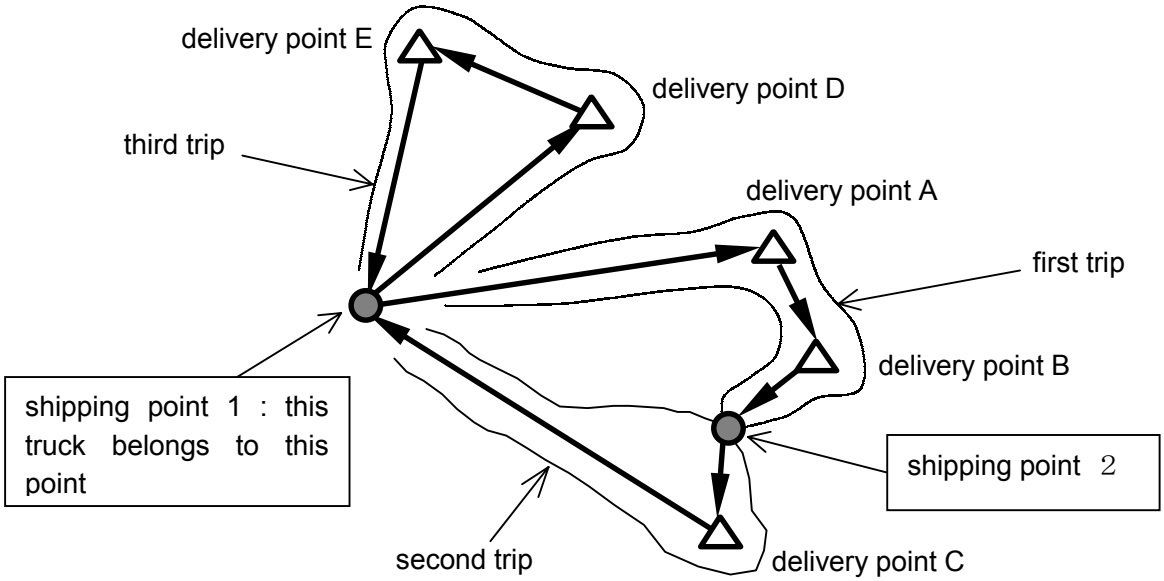

Fig 2. One-day run example of a truck

A tank truck is shipped petroleum products onto at a shipping point, runs to a delivery point (delivery points), is unshipped products from, and runs to the next shipping point. This run from a shipping point to the next shipping point via delivery points is called “trip” or “round.” Each trip usually has one shipping point, but it sometimes has a few delivery points of small quantity for an efficient delivery. Each truck starts in the morning from the shipping point that the truck belongs to, gets it back in the evening after several trips, and ends the day’s schedule.

2.3 Dispatch scheduling

Dispatch scheduling is to allocate all orders to trucks, to decide the shipping points and the delivery sequences, and to decide each truck's time schedule.

Scheduling results include the following of each truck;

- Each trip
  - start time and end time of shipment
  - start time from shipping point and arrival time at delivery point
  - start time and end time of unshipment
  - start time from delivery point and arrival time at next delivery point (not for every trip)
  - start time from delivery point and arrival time at next shipping point
- Lunch Break
  - start time
  - end time

2.4 Constraint logic programming

The history of constraint logic programming is shown in the reference [1], and now it has become a combination of "branch and bound" and "constraint propagation" to solve combinatorial problems. Constraint propagation is useful to find the regions of solution domain that do not satisfy the constraints and to suppress combination explosions during branch and bound.

Application development using constraint logic programming consists of the following procedures;

(1) define the constraints,
(2) define the evaluation function,
(3) determine the order of generating the solution, in other words, giving unknown variables a temporary value.

In addition, the function to reduce a value domain of unknown variables by constraint propagation, the function to judge if constraints are satisfied or not, and the function to optimize are needed. However, because developing tools with these functions are nowadays on the market, application developers do not have to develop these functions.

Constraint logic programming efficiently deletes solution domain that do not satisfy the constraints by constraint propagation, and so in the case that there are many constraints, this method is more efficient than other ones.

There are so many constraints in tank truck dispatch scheduling that constraint propagation works efficiently, and so constraint logic programming is considered suitable for tank truck dispatch scheduling.

2.5 Constraints

(1) Constraints about time

1-1. Each order has a designated delivery time bucket.
1-2. Each shipping point has a shipping time bucket.
1-3. Each truck must get back its belonging shipping point by the designated time in the evening.
1-4. The distances and running speeds are needed to judge if the above constraints are satisfied. The distances here are along roads, and the speeds here should be determined considering traffic jam.

(2) Constraints about trucks

2-1. Each truck's tank is divided to several 2kl and 4kl hatches, and so a tank truck has not only a quantity limitation but also a hatch limitation. For example, 7 oil types each quantity of which is 2kl cannot be shipped onto a 14kl tank truck with 3 2kl-hatches and 2 4kl-hatches.
2-2. Each truck has designated oil types that can be shipped onto the truck.
2-3. Each delivery point has an upper limit of truck capacity that is decided from road widths and land shapes.

(3) Constraints about shipping points

3-1. Some shipping points restrict oil types.
3-2. Each shipping point has an upper limit number of trucks that can be shipped simultaneously.
3-3. For some shipping points, total shipping quantity of each oil type has an upper or lower limit for a month or a week.

2.6 Evaluation function

The total cost is adopted as the evaluation function, and the objective is to minimize it. The total cost is the summation of transportation costs and shipping costs. Daily schedule is independent of the fixed costs, and so the total cost here excludes the fixed costs and consists only of variable costs.

However, to minimize the total cost including fixed ones is the final and long-term goal. This is described in detail in the "transportation cost" item.

(1) transportation cost

There are "Charter" and "Spot" as truck hiring way. Charter is a monthly or yearly contract, and the fixed costs are high and variable ones are low. Spot is an on-demand contract, and the fixed costs are low, and variable ones are high. Therefore, as to a daily scheduling, it is good to allocate as many orders as possible to charter trucks in order to make the total cost lower.

On the other hand, for a long-term cost minimization, it is necessary to know the optimal numbers of charter and spot trucks at the contract renewal time. As well as daily scheduling results, case studies with various numbers of charter and spot trucks are useful, and the fixed costs have to be included for this consideration.

(2) shipping cost

Shipping cost of unit volume petroleum is given for each shipping point. In ascending order, shipping costs are that of the company's own refinery, the company's own oil terminal, another company's refinery, and another company's oil terminal. Oil terminal's shipping cost is higher than refinery's one because of the transportation cost from refinery to oil terminal by tanker or train.

2.7 Solution generation procedure

Even though constraint logic programming suppresses combination explosion by constraint propagation, it takes a quite long time to search all domain of truck dispatch scheduling. It is much longer than we can use to make a daily schedule

Therefore, it is necessary for an efficiency to install a suitable solution generation procedure in the program so that ending the calculation in a daily acceptable time length do not cause any problems.

When implementing solution generation procedures in branch and bound, it is necessary to implement priorities of variables and values at each choice point. There are two types of these priorities. One is easily decided by the characteristics of evaluation function, and the other is heuristic.

In the case that a heuristic rule is necessary, many rules were tested and the best one has been finally adopted.

2.8 Scheduling

(1) Unit of scheduling

Almost all one-day runs of truck start in the morning and end in the evening of the same day, and so a schedule is made for a day. The whole country (Japan) is divided to 4 or 5 areas, and each area's schedule is made separately. Petroleum products are labeled into two groups, white (gasoline, kerosene, etc.) and black (heavy oil, etc.), and each tank truck is used only for a petroleum group of the two. Therefore, each petroleum group's schedules is made separately.

(2) Calculation time

This software runs on PC, and it takes about 10 to 30 seconds to automatically obtain a schedule. This time length can be accepted to make a daily schedule, and enough time is left to manually allocate the orders that are unallocated by automatic allocation or to reschedule after changing a few constraints.

(3) Treatment of unallocated order

Dispatch schedule is automatically made by the software, but all orders are not always allocated to trucks. The reasons are the followings.

3-1-1. There are more orders than truck capacities.

3-1-2. Many orders are concentrated on certain truck specifications or on certain delivery time buckets.

3-1-3. Some orders have a difficult constraint. It is sometimes impossible to satisfy it even alone, but in other cases, a combination of difficult constraints is impossible to satisfy.

Unallocated orders have to be finally allocated even by the following;

3-2-1. Asking a customer to accept an order change such as later delivery time.

3-2-2. Increasing available trucks.

3-2-3. Ignoring some constraints. For example, some trucks get back the belonging shipping point after the one-day run later than the constraint designates.

It is difficult for all these procedures to be automatically carried out. This software has the function to manually modify the schedule on display. The special constraints or priorities that are valid only on the day can be considered using this function.

3. Second example : paper product transporting trucks

This software has been modified and applied to truck dispatch scheduling for paper products. The main differences between petroleum and paper are the followings, and these functions are added to paper product transporting truck scheduling system.

3.1 Loading possibility check

Petroleum is liquid and loading possibility check has to be carried out only about weight and volume. On the other hand, paper is solid and so loading possibility check has to carried out about shape and size as well as weight and volume.

3.2 Division of loads

Quantity and necessary hatches of a petroleum delivery order usually does not exceed trucks' one. On the other hand, paper delivery order's weight or volume often exceeds truck capacity, and such orders have to be automatically divided.

3.3 Necessity of distances along roads

There are fewer shipping points and delivery points than in petroleum tank truck scheduling. A running distance of a truck is much longer than that of petroleum tank truck, and most trucks have just one trip a day. So distances along roads are not very important.

Other features of paper product transporting trucks than the above are similar to petroleum tank trucks.

4. Conclusions

This scheduling system has been introduced to several companies, and it is used for daily scheduling and for case studies about a new investment or a new contract of trucks and shipping points. Many users say that solutions where all constraints are satisfied are obtained from this system in a short time

This software has been applied to petroleum and paper so far, but it can be applied to many other materials with a small modification.

References

[1] edited by Fuchi, K.; Constraint Logic Programming, Kyoritsu Press, 1989. (in Japanese)