PSA PEUGEOT CITROËN

Solving the car sequencing problem using combined CP/MIP for PSA Peugeot Citroën

PSA Peugeot Citroën is a world-class automobile manufacturer with about 5.8% of the global market, and is Europe's No. 2 carmaker with a market share of 15.5%. It sold more than 3.2 million vehicles world-wide in 2002. The group comprises two volume carmakers, Peugeot and Citroën, each with its own identity, personality, marketing drive and global ambitions.

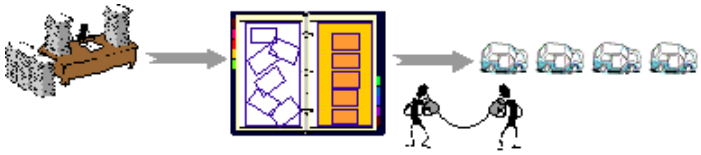
Innovation plays a vital role in PSA Peugeot Citroën's growth policy. The group has invested heavily to foster the development of new ideas in automotive styling, concepts and technologies. This strategy has already produced numerous tangible achievements. More than €1.7 billion was spent on Research and Development in 2001. Innovation means being able to quickly bring to market a wide range of products that meet customer requirements in terms of quality and safety while respecting the environment.

Problem/opportunity

To further these objectives we also have to break new ground in production. This application is a classic problem of automotive production: the car sequencing problem. For constant improvement, we keep on studying this problem.

The cars we produce are cars that have been ordered by a customer. Each customer can choose between many options that make his car special. That's why there is a big diversity of cars produced in the same plant - for example, in Poissy we only produce the 206, but each car may have a different engine, gearbox, colour, seats, etc.

Every day, the plant receives a batch of car orders. For each car we have to plan when and where it will be produced, according to its characteristics. This planning is made 5 days before the car's arrival in the first shop (the body shop) so that we can order certain items (synchronisation of car and component flow). So each day we have to schedule for 5 days production. For each car, we have to determinate its position by day and by assembly line. This sequence must respect the production constraints.



A plant is composed of 3 shops - the body shop, the paint shop and the assembly lines - and each shop has its owns particular constraints. For example to optimise paint shop operations it is better to group cars of the same colour in convoy ("densification"), whereas for the assembly lines, the separation of sun-roof cars and prohibition of consecutive air-conditioned cars will balance the operator task load ("smoothing"). We must always of course respect the capacity constraints. Therefore in order to compute the build sequence we have to take into account all these constraints. There are many cars to schedule with many constraints to respect. This is a large optimisation problem.

Why was this problem/opportunity selected?

PSA Peugeot Citroën's current technology for solving this problem uses linear programming (LP) and an in-house algorithm.

Different approaches to solving the problem have been investigated before. In 1997-98, a constraint programming (CP) prototype was developed using the global constraints of CHIP, which divided the problem into two parts and solved them separately (in succession in fact). The aim was to schedule one-day demand of cars on a single production line. The initial results were interesting, but further work was required in order to take account of revised requirements.

The LISCOS project proposed the combination of the LP and CP approaches. We saw in the possible dialogue of

these two methods an opportunity to have a more comprehensive view of the problem. Thus we may have only one optimisation instead of two separate optimisations. Moreover we hoped to have better results than with CP alone.

Description of technical solution

Two different models were tested during the LISCOS project. The first model is a two stage MIP/CP approach. First the MIP (mixed integer programming) module gives for each car the production day, the production line and the position within this day and line, taking into account many of the constraints. Then the CP module tries to improve the solution while guaranteeing that certain constraints are respected. We hoped that providing the MIP solution as a starting point would help the CP module find a solution that respected global constraints, but it can't be used to solve large problems because there are too many variables in the MIP module.

The second model is based on a hybrid MIP/CP approach. The MIP module defines for each day and each line which cars will be produced. Only capacity constraints are taken into account in this module. The CP module gives for each car the position in the day and line of production respecting the other constraints. There is a communication between these two modules, which is a LISCOS added value. The MIP module is used first, which calls the CP module for each day and line, giving the first result. This is evaluated and the resulting strategy is fed back to the MIP module that recalls CP and so on.

Benefits

The hybrid approach, combining MIP and CP technologies, that was developed in the LISCOS project is clearly a good solution approach for the PSA applications. The results of the prototype are promising.

The decomposition of the application into two tightened sub-problems, planning (solved by MIP) and sequencing (solved by CP), helped us to focus on the specific constraints of each sub-problem. In particular, the project has shown that the hard smoothing constraints have a large impact on the problem, and that it is very important to allow these constraints to be relaxed at the beginning of the solution process. Many requirements are contradictory and all of them are important from the users' point of view. The LISCOS project helped us to develop a methodology for finding compromises during the search for a good solution.

The prototype developed helped us to appreciate the various difficulties of the application: multi-criteria, large combinatorial search, MIP and CP models. From the beginning of the project, we knew that the application was complex and required a lot of energy and manpower. The results obtained are successful and are of great of importance from different point of views (methodology, technology, models) on future investments, developments and improvements of the current application.