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ADVANCED DECISION SUPPORT TOOLS FOR DISTRIBUTION PLANNING AND PALLETS LOADING

The good quality distribution and pallet loading plan plays very important role in the transportation process. Effective information systems should be able to take into account at the same time many complex industrial specific constraints in loading and distribution activity to build high quality plan. The paper presents technological solution based on powerful heuristic algorithms and constraint programming to build for the whole Europe realistic distribution and loading plan for furniture industry.

ZAAWANSOWANE NARZĘDZIA DO WSPOMAGANIA KALKULACJI PLANÓW DYSTRYBUCJI I ZAŁADUNKU PALET

Wysokiej jakości plan dystrybucji i załadunku palet odgrywa ważną rolę w procesie transportu. Wydajny system informatyczny powinien być w stanie uwzględnić w tym samym czasie wiele specyficznych branżowo wymagań w zakresie załadunku i dystrybucji towarów, aby zbudować wysokiej jakości plan. Referat prezentuje najnowsze rozwiązania oparte na wydajnych algorytmach heurystycznych i technice programowania z ograniczeniami, w celu zbudowania dla całej Europy realistycznego plany dystrybucji i załadunku palet na przykładzie branży meblarskiej.

1. INTRODUCTION

Transportation managers within consumer packaged goods companies face many challenges in the process of trying to create cost effective, executable routing plans. Nowadays, advanced planning and scheduling of routing systems can support these complex requirements. It provides managers with the flexibility and the decision support tools they need to create schedules that consolidate these kinds of real-word tradeoffs. This routing and scheduling systems contain very powerful algorithms, which are based on state to art mathematical and artificial intelligence achievements. At this paper heuristic algorithms and constrains programming technology techniques for solving many types of complex vehicle routing problems will be shown.

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In 1947George Dantzig invented the simplex method for linear programming. Fifty years later, linear programming is now a strategic technique used by thousands of lines of business trying to optimize their operations. In the mid-1980s, researchers developed constraint programming as a computer science technique by combining developments in the artificial intelligence community with the development of new computer programming languages. Fifteen years later, constraint programming is now an important technique to optimize complex and over constrained business operations. In the mid-1990s significant research has been made in improving the search methodology to find a very good solution to these problems. Many simple greedy methods have been replaced by meta-heuristics. The Simulated Annealing (SA) and Tabu Search (Tabu) in many cases can provide a better solution for complex problems than it was done before. The Fig.1. shows on the time line the progress of new decision support tools introduced on the market.

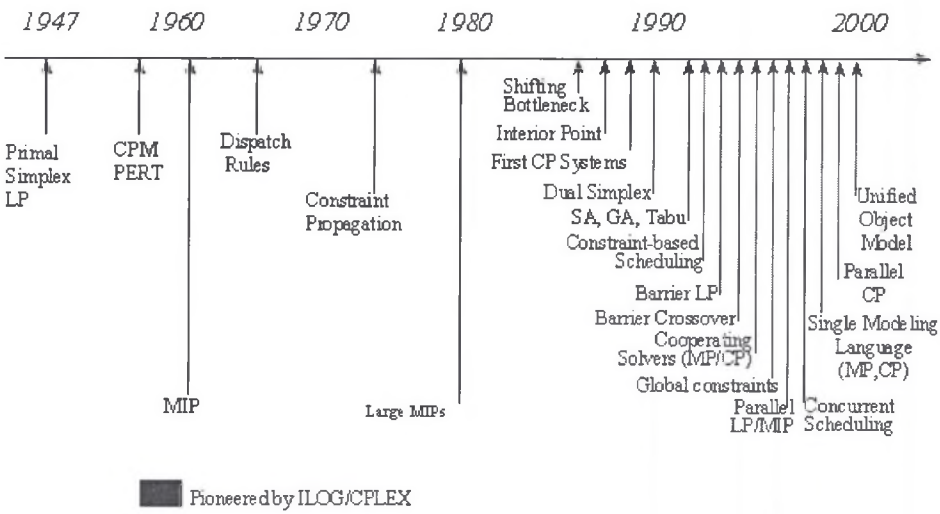

Fig.1. Progress in decision support tools

2. DISTRIBUTIONS MODEL

The goods can be delivered by truck in various ways. The travelling salesman problem (TSP) is the simplest technique of delivering goods. A salesman is required to visit each of n given cities once and only once, starting from any city and returning to the original place of departure. Because of real constrains many companies have to deliver goods by multiple vehicles. The vehicle routing problem (VRP) goal is to build a set of routes, so that each visit is performed exactly once. The aim is to minimise the global cost of these routes. The Fig.2. shows possible routing plan.

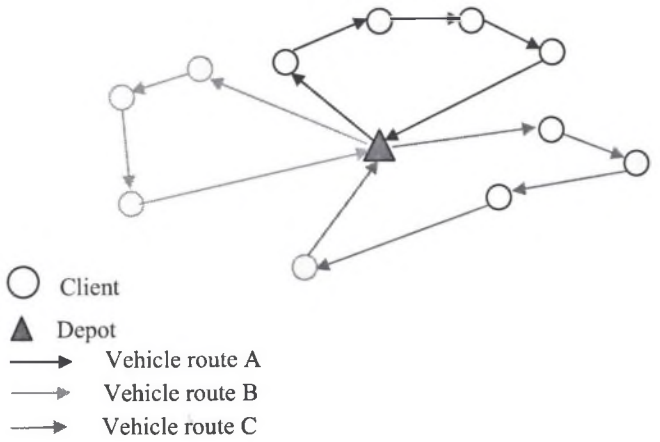

Fig.2. Vehicle Routing Problem

Real-world problems involve extra constrains on capacity, time, route and sequence of visits. This capacity may be measured in weight, volume, length, width, number of pallets, etc. The customer can expect delivery in the period of time during which a vehicle can make visit. This period is called time window. All these constrains can have substantial influence on distribution plan.

For the reason specific to a given problem, route can also be limited in their length, their duration, or the number of customers they visit.

The simple Vehicle Routing Problem can be solved with many objectives. We can have main objectives to reduce the number of vehicles before minimising distance or time. We can formulate the VRP that all vehicles after the last visit will not continue their route and will not return to depot. The Fig.3. shows possible routing plan for this type of VRP.

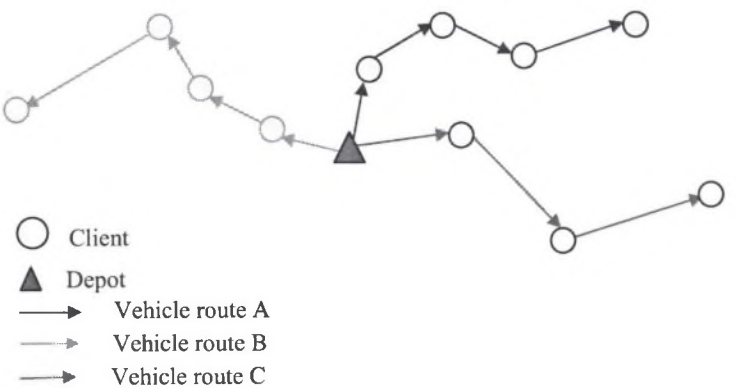

Fig.3. Vehicle Routing Problem without return to the depot

For furniture industry it is important to calculate VRP and pallet loading plan in the same time. In the following part of this paper, it will be explained how two NP-hard problems can be solved together in reasonable time.

3. CONSTRAINT PROGRAMMING

The constraint programming has successfully automated the solution to complex combinatorial problems in many domains as diverse as planning, allocating resources, managing time, organizing personnel, cutting materials, blending mixtures, assigning radio frequencies, and many others. The success of constraint based technology has resulted in a considerable amount of research effort aimed at producing ever more effective and efficient ways of tracking constraint satisfaction problems. The effectiveness of constraint programming lies in the fact that it dissociates the representation of the problem from the search algorithms used to solve it. Constraint programming is a computer programming technique, with a name that is in the spirit of other programming techniques, such as object-oriented programming, functional programming and structured programming. With constraint programming, a problem is represented in terms of its unknowns, that is, its variables, and in terms of the constraints that must be satisfied by these variables. Thus, for any given problem, the problem representation consists of declaring the variables and posting the constraints on them. Solving such a problem then consists of finding a value for each variable while simultaneously satisfying the constraints.

4. OPTIMALIZATION MODEL

Constraint programming techniques compose of two relatively distinct activities. The first activities are a problem representation. Problem formulation is an extremely important part of problem solving. The problem representation consists of the declaration of the unknowns and the constraints of the problem. The unknowns are called constrained variables. Each of these constrained variables can be associated with a set of possible values called the domain of the variable. When the domain of a variable contains only one value, we say that the variable is bound and we set the value for the variable.

The second activities involve solution searching. Solving the problem consists of selecting a value in the domain of each constrained variable, so that all the constraints are satisfied. In the real word we have to optimize some given criterion to find its maximum or minimum value.

The Fig.4. shows general algorithm, which guides and controls the search process.

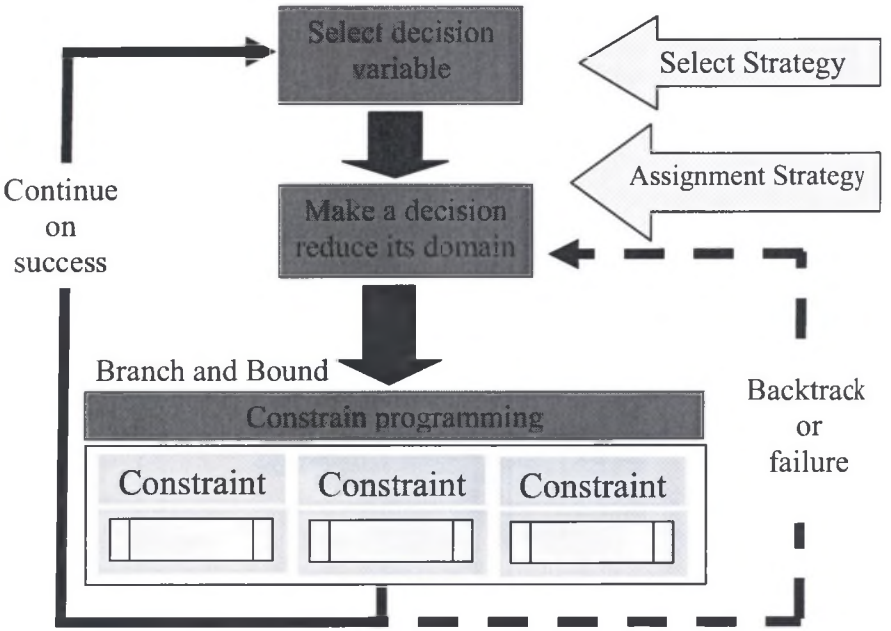

Fig.4. The Search Process

There are numbers of search algorithm which help to find the best solution in the shortest time. The Search process shown in the picture explains how a branch and bound algorithm is used to propagate constrains over all decision variables in the model. There are two main type strategies of finding a solution. The first one is to search all possible sdutions. However in real decision problems like vehicle scheduling it will take tremendous time to find the optimal solution. Meta-heuristic algorithms can bring very powerful approacl to find an almost optimal solution for many difficult problems in a shorter time.

5. FINDING THE SOLUTION

In many routing problems, good solutions must be computed very quickly. However, the computational complexity of routing in general makes it impractical, except for very small problems with less than 30 visits. We can use complete search methods such as branch and bound to obtain the optimal solutions for small size problems. I use two-phase approach for bigger size vehicle routing problems. The first phase consists of generating a soluton that satisfies the problem at hand. This preliminary solution can be generated with one of the greedy heuristics like "sweep heuristics", "neatest-to-depot heuristic" or "nearest addition heuristic". In phase two, the solution is improved using a variety of heuristics. These methods are based on local search and iterative improvement techniques.

Before we start creating distribution plan, we first have to build pallets of furniture. I developed heuristic algorithms which can build pallet composed of different size of boxes. Every visit can have one or more pallets, which should be loaded on truck close to each other. The Fig.5. shows example of big size pallet.

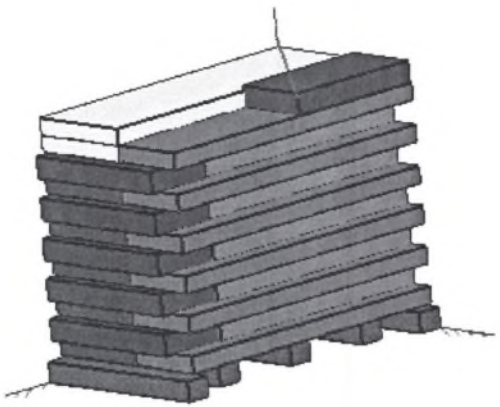

Fig.5. Complex pallet of different box size

The distribution planning and pallet loading system is composed of two models. The main model is responsible for building or improving the quality of the vehicle route. The second model called submodel finds the best placement of the pallets on the calculated truck. Each time as a new visit is added or removed to the route, the submodel is called by the main model to give the answer if all pallets of all visits in the route are loaded. The submodel has to find feasible loading of pallets which is coherent with sequence of the truck visit. The Fig.6. shows example of loading pallets. Each colour (degree of grey) is assigned to appropriate visit.

Fig.6. Pallet loading on truck

I use local search techniques to calculate the good distribution and pallet loading plan. These methods in every step calculate better solution. However, the ways in which improving moves are accepted, it must be carefully controlled to prevent the search from moving to very poor solutions. This more subtle control is provided by what we term meta-heuristics. This mechanism has capability to escape from local minimum and allows finding high quality solution.

6. CONCLUSION

These heuristic algorithms and constraint programming technique was used in OptiTrans system. The system equipped with an electronic map is currently working in a big furniture company in Poland for calculate distribution and pallet loading plan. It can load orders form SAP R/3, build 800 pallets and create distribution and loading plan for 350 customers in different countries throughout Europe. The whole planning process takes five minutes on Intel Pentium 800Mhz. The figure 7. shows real example of distribution plan from one loading depot in Poland to many cities around the Europe.

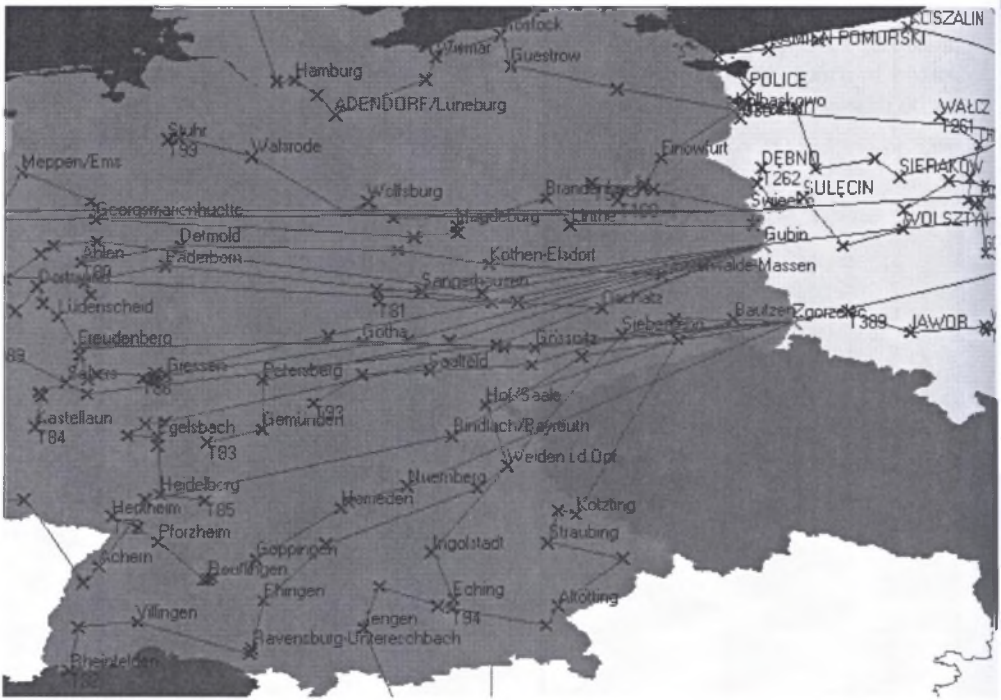

Fig.7. Distribution plan

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