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Metaheuristics for Transport and Logistics

IDSIA, Istituto Dalle Molle di Studi sull'Intelligenza Artificiale is a research institute active in both theoretical and applied research in the field of Operations Research and Artificial Intelligence. Since 1996 IDSIA has capitalized on the results obtained in the theoretical field applying them to real world logistics and transport applications. In this communication we outline the major results we have obtained in combinatorial optimisation problems, and their applications to real-world problems. We also show how the real world provides a source of continuous inspiration to solve theoretical problems that can be later applied to a real problem.

Metaheuristics and hard combinatorial optimisation problems

Most problems faced by logistics operators have been known for centuries, think of the Chinese postman problem, first formulated by Euler in 1736. These problems have the ugly characteristic of being combinatorial, that is, all the possible combinations of the decisions and variables must be explored to find a solution of the problem. The downside of this is that as the number of decisions and variables increase (and in real world problems is quite easy to find problems with hundreds of variables) the time required to find a solution becomes rapidly unaffordable.

Heuristics methods have been devised to explore only parts of the search space, concentrating in those parts that appear to promise a probable improvement of the solutions, thus reducing the time required to obtain a solution, which is often sub-optimal, but already a good improvement from the starting situation. A heuristic makes use of peculiar characteristics of a problem and exploits them to find a solution. Other empirical methods do not exploit only the problem characteristics but especially the analogy with other optimisation methods found in Nature.

Such heuristic methods, independent of the problem, are called Metaheuristics.

Ant-Colony Optimisation (ACO) is such an heuristic[2]. Based on the observation that ants find the optimal path between a food source and their nest, a computer analogy has been implemented and applied to various problems, ranging from the travelling salesman problem, to the sequential ordering problem [4] and the vehicle routing problem [3]. Other metaheuristic methods are Genetic Algorithms, Simulated Annealing, Tabu Search. IDSIA is currently involved in a European project called "Metaheuristic network". This thematic network comprises a number of leading European research institutes and its aim is to measure the performance of different metaheuristics when applied to different problems.

Integrating optimisation problems at different levels: the LSCT project

This project has been developed in collaboration with ContShip La Spezia Container Terminal. The project was financed by the Swiss CTI.



Techniques

*Time series analysis
Mixed integer programming
Flexible job-shop scheduling
Discrete Event Simulation*

Metaheuristics are a powerful tool to solve combinatorial optimisation problems which are

so frequent in logistics and transports, but they cannot be applied blindly. It is only with a judicious combination of old and new methods that we have been able to solve the problem of improving the performance of the intermodal container terminal in La Spezia in the contest of a CTI/KTI sponsored project [4]. The scale of the problem involving many decision makers at different levels (yard managers, ship planners, resource allocators) made the problem intractable, even by the most advanced optimisation methods currently available. Our approach was based on a decomposition of the problem at different levels, on different time scales. We focused on the ship loading and unloading process, but first we formulated the resource allocation problem as a network flow problem: how many quay cranes and yard cranes are necessary to sustain a flow of container from the ship to the yard (and back) to unload and load the ship within the deadline? Once this problem has been solved, with the traditional mixed integer programming approach, we concentrated on the scheduling of the load/unload sequence, devising a new job-shop heuristics to solve this hard problem [5].

Simulation and optimisation: PLATFORM

This project was financed by the EU - DGVII



Techniques

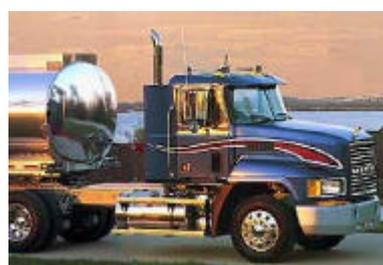
*Discrete Event Simulation
Autonomous agents*

Simulation played an important role in this project, as it did in the EC-sponsored project PLATFORM, where the objective of the work was to evaluate the impact of advanced logistics systems in rail-road intermodal hubs. The experience of PLATFORM [8] showed how simulation can be used to provide to the logistic managers a very detailed model of the process they manage, removing many of the assumptions used to formulate the optimisation problem. It has been observed that these assumptions are

often rejected by the terminal managers since they think that they impose an over-simplification the problem. While this often is a valid objection, their next step is to refuse any kind of management policy based on the assumptions. Simulation can provide the common ground where managers and operations research specialist converge to a shared vision of the problem.

ACO for vehicle routing: the DYVO project

This project has been developed in collaboration with Pina Petroli s.a. in Grancia. The project was co-financed by the Swiss CTI



Techniques

*Ant Colony Optimization
Forecasting
Simulation
On-line Planning*

The Ant-colony optimisation metaheuristic is finds an application to the problem of heating oil distribution in Canton Ticino [1]. This CTI/KTI sponsored project aims at the development of a software prototype able to employ ACO to the solution of the vehicle routing problem with time windows and with a non-homogeneous fleet of vehicles. Pina Petroli is our test site and we have developed an application which, accessing their database of customers' orders, returns a distribution plan, which is the list of customers to be visited over a given time horizon, minimising the travelled distance. The tool has been designed in order to let the human decision maker (the Tour Planner) to experiment with the computer generated solutions, to quickly recompute a new solution in face of changed conditions (a truck breakdown, a road blockage, an urgent customer request) thanks to the extreme rapidity of the ACO metaheuristics in finding a new solution (only 2 minutes for a whole week of deliveries, with more than 100 orders).

**Dynamic and time dependent VRP: the
MOSCA project**

This project was financed by the EU Commission



Techniques

*Metaheuristic
Ant Colony Optimization
Stochastic Optimization
On-line Planning*

IDSIA is now taking part in a new European project, named MOSCA, which aims at the production of a decision support system for the delivery of goods in urban environments. Most traffic management systems do not take into account commercial traffic in their models and this can lead to gross errors in estimating time of travels on road segments, due to the ignorance of road blocks caused by delivery operations in front of shops. MOSCA aims at improving the management of urban traffic providing assets to both commercial transport operators and to city traffic managers. The former will be able to access state-of-the-art vehicle routing algorithms [3] which make use of privileged traffic information provided by the city administration. The latter will use the information on planned deliveries to mitigate the effects and smooth the traffic flow, reducing both the economical and the environmental impact. The role of IDSIA is to develop vehicle routing algorithms which are customised to the urban situation, where travel times on road segments are highly variable and the knowledge of this variability must be capitalised and used efficiently.

In conclusion, we have seen in the recent years a great effort in the integration of logistics with the existing data exchange infrastructure. We think that this integration and data availability brings great opportunities to make an intelligent use of the data and Operations Research techniques are ready to take this chance.

The Spin-Off company: AntOptima



AntOptima has been founded in 2001 as a spin-off of IDSIA. AntOptima has signed an agreement with IDSIA in which AntOptima has the duty to develop research applications of algorithms and theoretical results obtained at IDSIA, while continuing to support IDSIA research thanks to a strict co-operation with the institute.

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