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**IDSIA**
**Istituto Dalle Molle di studi**
**sull'intelligenza artificiale**

# Optimization in 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 capitalize 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 Metaheuristcs.

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][12]. Other metaheuristic methods are Genetic Algorithms, Simulated Annealing, Tabu Search. IDSIA was 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 [6]. 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[8] [9].

***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 [10] 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][2]. 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 has participated 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[11].

***EcoLogTex: a-Tool for Ecologic Economic Supply Analysis and Optimization in The Textile Industry***

*This project was financed by the SWISS KTI Commission*

HUGO BOSS


**Techniques**

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

More and more consumers value textile products made by respecting the environment and the workers, while still having a reasonable price.
This project will deliver a new methodology and a tool to evaluate alternatives for textile supply chains taking into account the impact on the environment (using the Life Cycle Assessment approach) as well as costs, while satisfying corporate social responsibility constraints.
The proposed methodology will use information from both the environmental and economic perspective to generate supply chain alternatives which are robust to the inherent uncertainty in the estimation of all parameters (environmental impact, costs and time)
The outcome of the project is expect to bring a commercial advantage to HUGO BOSS as they will be able to improve planning and monitoring of their supply lines with respect to emerging market standards. The project will also have a positive impact on the environment, as more "environmentally friendly" processes are expected to be favoured.

***WHATIF: Wagon Handling based on Ant Theory for Intermodal Freight***

*This project was financed by the SWISS KTI Commission*

**Techniques**

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

Hupac is the leading company in the combined transport through Switzerland and one of the main operators in Europe. The company engages itself in order that more and more goods can be transported by rail instead than by road, contributing in this way to modal shift and environment protection.
The goal of the project is to develop an innovative decision support system to improve tactical and operational planning of combined transport logistic operators. Intermodality is the way forward in the transportation business, as environmental and economic concerns make road-only transport less attractive. Still, combined transport operators are facing tough competition by road only transport in this transition period and they are in great need of tools and methodologies to improve the performance of their operations. The WHATIF project aims to deliver a decision support tool able to improve the efficiency of train disposition by 8-15 %, thus providing a sensible cost reduction.
The objectives of the project are:
1. Evaluate and signalize the impact of traffic irregularities (train delays; lack of compositions; maintenance needs, etc.)
2. Calculate and propose a series of possible alternatives to the problems above-mentioned
3. Calculate the rotation of the compositions (including the base situation in relation to the train circulation plan)
4. Monitor periodically the compositions and signalize when these wander too much from the prefixed standard in term of wagon types.
5. Take into consideration the maintenance status of the wagons (and/or compositions) in order to calculate and signalize eventual needs to block/discard.


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