Preface

The LAMSADE[1] was established in 1976 as a research laboratory jointly funded by Paris-Dauphine University and the CNRS (the French National Science Foundation) oriented to decision aiding, mainly in the areas of multiple criteria decision aiding and linear programming.

It very soon aggregated the research activities on computer science conducted within Paris-Dauphine University. In 30 years the LAMSADE gained a world-wide reputation in operations research and decision aiding, while developing and strengthening a specific vision of computer science, that is management and decision oriented computer science (from the French term “informatique décisionnelle”). Today the LAMSADE is one of the very few research laboratories showing such originality in its research orientation.

During these years new specific research subjects came to enrich those already existing: multi-agent systems, distributed computing and databases. In this effort, the LAMSADE had to put together different interdisciplinary competencies: decision theory, operations research, mathematics, social sciences and several fields of computer science. At the turning point of its 30 years the LAMSADE is organizing its research activities around four principal areas:

1) decision aiding;
2) optimization and its applications;
3) multi-agent and distributed systems;
4) database systems, information systems and knowledge management.

Under such perspective, the laboratory’s scientific project mainly aims to:

1. Laboratoire d’Analyse et Modélisation de Systèmes pour l’Aide à la DEcision (Laboratory of Analysis and Modeling of Decision Support Systems).

– consolidate and extend our international leadership in operations research and decision aiding;

– strengthen and promote our vision of management and decision-oriented computer science;

– create new large interfaces between operations research and theoretical computer science.

In particular, research in the intersection of combinatorial optimization and theoretical computer science always remains a central key-point of LAMSADE's research activity.

Combinatorial optimization and theoretical computer science have been, and still are, considered as two subjects different from each other. If the difference is quite evident for some areas of both subjects, it becomes much less so if we think of areas such as complexity theory, theory of algorithms, solving hard combinatorial problems, graph theory and, more generally, discrete mathematics, etc. All these matters form a very large interface between combinatorial optimization and theoretical computer science. Historically, researchers in the areas mentioned above have been members of two distinct major scientific communities, namely theoretical computer science and operations research. They have addressed almost the same problems, worked under the same paradigms, used parallel formalisms, tools and methods and developed either parallel or complementary approaches. The fruits of this "separate research" have impregnated the entire field of information technology and industry and almost the whole of what is considered today as management sciences. Moreover, they have been widespread over numerous scientific disciplines, initially orthogonal to both computer science and combinatorial optimization, giving rise to new areas of research. However, if from this "separate attack" we witnessed the emergence of practically all of the traditional concepts dealing with complexity theory, discrete mathematical modeling and polynomial approximation of discrete optimization problems, numerous problems and challenges remain open and without satisfying answers, thus the need for intensive research in the interface of combinatorial optimization and theoretical computer science becomes not only clear but also extremely challenging. This kind of research is one of the major directions in the scientific project of the LAMSADE.

With such studies, we expect to advance in the research for new paradigms, getting an insight mainly from the complex system sciences. I strongly believe that in the near future, the themes of our research will be central to operational research and will reshape the research landscape in combinatorial optimization. I also believe that they will influence all the active research for new calculating machine paradigms based upon properties of natural and human systems that are not exploited by conventional computers, by providing them with new problems to deal with and new solutions to try out. Our scientific project can thus be seen as an initiative to drastically renovate the research agenda in combinatorial optimization, by addressing open and novel problems arising from complex human systems. In order to achieve this objective, we have first to support a research environment that overcomes traditional cluster barriers among communities historically defined as "operations research" and "theoretical computer science". We have also to work over the common basis of established theories and expertise for studying decidability, complexity, structure and solutions of hard optimization problems, which will definitely serve as the framework for validation of any advances in new research topics.

As stated above, bringing together operations research and theoretical computer science can be the first step in developing close synergies between all the complex systems disciplines, mainly those based upon the study of human systems. Research in the interface of these subjects is the main attempt to build such a broad alliance and to give it a clear scientific status. Moreover, by handling novel problems issued by still unexploited models and working hypotheses, we aim to strongly contribute to the emergence of a new paradigm for both combinatorial optimization, and algorithmic and complexity theory aspects of theoretical computer science.

The main objective of the book is to bear witness to the quality and the depth of the work conducted in the laboratory along the epistemological lines just outlined. In the chapters, the reader will find all the ingredients of a successful matching between combinatorial optimization and theoretical computer science, with interesting results carrying over a large number of their common subjects and going from "pure" complexity theoretical approaches dealing with concepts like **NP**- and **PSPACE**-completeness to "oldies but goodies" and always essential and vital operational research subjects such as flows, scheduling, or linear and mathematical programming, passing from polynomial approximation, online calculation, multicriteria combinatorial optimization, game theory, design of algorithms for multi-agent systems, etc. All of the chapters make a valuable contribution to both the two main topics of the book and any of the areas dealt.

In Chapter 1, Aloulou and Della Croce deal with single machine scheduling. They consider scheduling environments where some job characteristics are uncertain, this uncertainty being modeled through a finite set of well-defined scenarios. They search for a solution that is acceptable for any considered scenario using the "absolute robustness" criterion and present algorithmic and computational complexity results for several single machine scheduling problems.

Although the approximability of multi-criteria combinatorial problems has been the inspiration for numerous articles, the non-approximability of these problems seems to have never been investigated until now. Angel *et al.* in Chapter 2 propose a way to get some results of this kind that work for several problems. Then, they apply their method on a multi-criteria version of the traveling salesman problem in graphs with edge-distances one and two. Furthermore, they extend existing approximation results for the bi-criteria traveling salesman problem in graphs with edge-weights 1 or 2 to any number k of criteria.

In Chapter 3, Ausiello *et al.* study online models for minimum set cover problem and minimum dominating set problem. For the former problem, the basic model implies that the elements of a ground set of size n arrive one-by-one; we assume that with any such element, arrives also the name of some set containing it and covering most of the still uncovered ground set-elements. For this model they analyze a simple greedy algorithm and prove that its competitive ratio is $O(\sqrt{n})$ and that it is asymptotically optimal for the model dealt. They finally deal with a new way to tackle online problems by using what they call "budget models". For the case of the minimum set cover problem the model considered generates the so-called maximum budget saving problem, where an initial budget is allotted that is destined to cover the cost of an algorithm for solving set-covering and the objective is to maximize the savings on the initial budget.

In Chapter 4 by Bérard *et al.*, Merlin-like time Petri nets (TPN) and timed automata (TA) are considered. The authors investigate questions related to expressiveness for these models: they study the impact of slight variations of semantics on TPN and compare the expressive power of TA and TPN with respect to both time language acceptance and weak time bisimilarity. On the one hand, they prove that TA and bounded TPNs (enlarged with strict constraints) are equivalent w.r.t. timed language equivalence, by providing an efficient construction of a TPN equivalent to a TA. On the other hand, they exhibit a TA such that no TPN (even unbounded) is weakly bisimilar to it. Motivated from this latter result, they characterize the subclass TA$^-$ of TA that is equivalent to the original model of Merlin-like TPN and show that both the associated membership problem and the reachability problem for TA$^-$ are **PSPACE**-complete.

Carello *et al.*, in Chapter 5, introduce a graph problem which is called maximum node clustering. They prove that it is strongly **NP**-hard, but it can be approximated, in polynomial time, within a ratio arbitrarily close to 2. For the special case where the graph is a tree, they prove that the associated decision problem is weakly **NP**-complete as it generalizes the 0-1 knapsack problem and is solvable in pseudo-polynomial time by a dynamic programming approach. For this case they devise a fully polynomial time approximation schema for the original (optimization) problem.

In Chapter 6, Chevaleyre tackles the problem of multi-agent patrolling dealt with as a combinatorial optimization problem. More precisely, territory (one of the inputs of the problem) is modeled by means of a suitable edge-weighted graph $G(V, E)$ and then the exploration strategies for this graph are based upon particular solutions of the traveling salesman problem. With this method, when the graph is metric, he obtains, in polynomial time, an exploration strategy with value bounded above by $3\mathrm{opt}(G) + 4\max\{w(i,j) : (i,j) \in E\}$, where $\mathrm{opt}(G)$ is the value of the optimal exploration strategy and $w(i,j)$ is the weight of the edge $(i,j) \in E$. It is also proved that, using another approach for the patrolling problem, based on a particular graph-partitioning problem, the multi-agent patrolling problem is approximable within approximation ratio 15, even in the case where the underlying graph is not metric.

In Chapter 7, Chevaleyre *et al.* investigate the properties of an abstract negotiation framework where, on the one hand, agents autonomously negotiate over allocations of discrete resources and, on the other hand, reaching an optimal allocation potentially requires very complex multilateral deals. Therefore, they are interested in identifying classes of utility functions such that, whenever all agents model their preferences using them, any negotiation conducted by means of deals involving only a single resource at a time is bound to converge to an optimal allocation. They show that the class of modular utility functions is not only sufficient (when side-payments are allowed) but is also maximal in this sense. A similar result is proved in the context of negotiation without money.

In Chapter 8, Della Croce *et al.* study two very well-known hard combinatorial problems, the maximum cut problem and the minimum dominating set restricted to graphs of maximum degree 3 (minimum 3-dominating set). For the former, they mainly focus on sparse graphs, i.e., on graphs having bounded maximum degree. They first use a technique based upon enumeration of cuts in a properly chosen subgraph of the input graph and then an extension of them in an optimal way to produce a cut for the whole instance. By means of this method they produce an exact algorithm for the weighted maximum cut problem with improved upper complexity bound in the case of sparse graphs. Next, they restrict themselves to the unweighted maximum cut problem in graphs of maximum degree 3 and devise a tree-search based exact algorithm. Exploiting some simple and intuitive dominance conditions that efficiently prune the search-tree, they provide a fairly competitive upper complexity bound for the case settled. Finally, they refine the search tree's pruning by introducing a counting procedure, based upon the introduction of weights for the fixed data, which allows them to measure in a more precise way the progress made by the algorithm when it fixes them. They apply this method to min 3-dominating set.

In Chapter 9, Demange *et al.* study the computational complexity of online shunting problems. They consider a depot consisting of a set of parallel tracks. Each track can be approached from one side only and the number of trains per track is limited. The departure times of the trains are fixed according to a given timetable. The problem is to assign a track to each train as soon as it arrives to the depot and such that it can leave the depot on time without being blocked by any other train. They show how to solve this problem as an online bounded coloring problem on special graph classes. They also study the competitiveness of the first fit algorithm and show that it matches the competitive ratio of the problem.

Chapter 10, by Demange *et al.*, surveys complexity and approximation results for the minimum weighted vertex coloring problem. This is a natural generalization of the traditional minimum graph coloring problem obtained by assigning a strictly positive integer weight for any vertex of the input graph, and defining the weight of a color (independent set) as the maximum of the weights of its vertices. Then, the objective is to determine vertex coloring for the input graph minimizing the sum of the weights of the colors used. Complexity and approximation issues for this problem are presented for both general graphs and for graphs where the traditional minimum graph coloring problem is polynomial.

Chapter 11 is a complement of Chapter 10 where, along the same lines, complexity and approximation issues are addressed for the minimum weighted edge coloring problem where, instead of vertices, edges are now to be legally colored.

In Chapter 12, Gabrel considers the Dantzig-Wolfe decomposition for 0-1 linear programming when a subset of constraints defines a independent set polytope. She compares linear relaxations of both the initial and master program (obtained by decomposing on independent set constraints) with respect to various independent set polytope representations. For perfect graphs (in particular for co-comparability graphs), the linear relaxation of the master program is easy to solve while for general graphs its optimal value cannot be calculated in polynomial time. Consequently, she proposes to decompose only on a subset of the independent set constraints (those associated with "polynomial" independent set problems) in order to define another master program for which the LP-relaxation is easy to solve and remains stronger than the traditional LP-relaxation of the initial program.

In Chapter 13, Gabrel compares several 0-1 linear programs for solving the satellite mission planning problem. She considers two models and explains why one of them systematically calculates lower upper bounds. Her explanation is based upon independent set polytope formulations for perfect graphs. Then, she proposes new upper bounds for some large-size benchmark instances.

Chapter 14, by Giannakos *et al.*, is a survey on some of the main results dealing with the problem of finding a Nash equilibrium in a game. After reporting several questions concerning complexity of general games (how many equilibria exist?, what are the conditions of the existence of an equilibrium verifying some given property?), the authors focus on games having pure Nash equilibria, as potential games and congestion games, for which they present several models.

In Chapter 15, entitled "Flows!", Koskas and Murat give another novel interface between operational research and theoretical computer science by showing how tools from combinatorics of words can be very efficiently used in order to devise "divide and conquer" algorithms in a number of operational research and computer science fields, like database management, automatic translation, image pattern recognition, flow or shortest path problems, etc. The current contribution details one of them, dealing with maximum flow in a network.

Milanič and Monnot, in Chapter 16, introduce the exact weighted independent set problem, consisting of determining whether a weighted graph contains an independent set of a given weight. They determine the complexity of this problem as well as the complexity of its restricted version, where the independent set is required to be of maximum size, for several graph-classes. Furthermore, they show that these problems can be solved in pseudo-polynomial time for chordal graphs, AT-free graphs, distance-hereditary graphs, circle graphs, graphs of bounded clique-width, and several subclasses of P_5-free and fork-free graphs. Monnot, in Chapter 17, deals with complexity and approximability of the labeled perfect matching problem in bipartite graphs, as well as with minimum labeled matching and maximum labeled matching in 2-regular bipartite graphs, i.e., in collections of pairwise disjoint cycles of even length.

In Chapter 18, Monnot and Toulouse present several standard- and differential-approximation results for the P_4-partition problem for both minimization and maximization versions.

Finally, in Chapter 19, Quadri *et al.* present an improvement of a well-known method, based upon surrogate relaxation and linearization of the objective function, for calculating an upper bound of integer separable quadratic multi-knapsack and report computational experiments that seem to confirm the efficiency of their approach.

I think that all these contributions show the vitality and the originality of the research carried out by the LAMSADE. I do hope that the reader will really appreciate the depth and the richness of all the presented contributions.

To conclude, let me say once more that it is always a pleasure for me to work with Chantal, Sami and Raphael Menasce, Jon Lloyd and their colleagues at ISTE Ltd.