Alessandro Agnetis – Curriculum vitae

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Alessandro AGNETIS was born in Rome (Italy) in 1963. He graduated in Electrical Engineering at the Università degli Studi di Roma "La Sapienza" in 1987.

1/11/1988 – 10/7/1992 PhD in Systems Engineering at the Università degli Studi di Roma "La Sapienza".

1/11/1993 – 31/10/1998 Assistant Professor of Automatic Controls, Dipartimento di Informatica e Sistemistica, Engineering School, Università degli Studi di Roma "La Sapienza".

1/11/1998 – 31/10/2001 Associate professor of Operations Research, Dipartimento di Ingegneria dell'Informazione, Engineering School, Università degli Studi di Siena.

1/11/2001 – present Full professor of Operations Research, Dipartimento di Ingegneria dell'Informazione, Engineering School, Università degli Studi di Siena.

1 Research

1.1 Routing in flexible manufacturing systems

A general look at combinatorial models for flexible manufacturing is presented in [77] and [76], where a summary of several applications is also given.

Models and methods for part routing in flexible systems can be classified into three classes, depending on the structure of the production system under consideration: *i*) flexible cells; *ii*) flow lines; *iii*) flexible manufacturing/assembly systems (FMS/FAS).

1.1.1 Flexible cells

In [5] a routing model is presented for a general cell architecture. The complexity of throughput maximization is analyzed, for different values of the number r of robots, the maximum number of parts present in the cell at the same time s, as well as the features of the process plan. If $s = 2$, and all operations require different tools, then the problem is polynomial (for any fixed r). If $s \geq 3$, and various operations may require the same tool, the problem is proved to be NP-hard even if $r = 2$. For $s \geq 3, r \geq 3$, the problem is NP-hard even if all operations require different tools.

In [3, 92, 12, 21] various real-life flexible cells are analyzed, and either exact or heuristic algorithms proposed. A careful study of tabu search heuristics is reported in [20].

In [11] the tool duplication problem for 2-machine flexible cells is considered. Given the operation sequence for each machine, the problem is to select at most h tools such that their duplication is most profitable from the viewpoint of throughput. For general h this problem is NP-hard, but it becomes polynomial if all operations require different tools.

1.1.2 Flow lines

In [7, 19] the problem of assigning operations to machines of a flow line is addressed. This is close to the classical Assembly Line Balancing problem, except that here a finite number of parts is considered, and the objective is makespan minimization (rather than workload balancing). Polynomial dynamic programming algorithms are proposed. In [9, 18] two case studies are analyzed, the former concerning the assembly process of car radiators, the latter concerning the experimentation of push vs. pull dispatching rules (see also [93]) in a large car assembly plant.

1.1.3 FMS and FAS

In [6], two linear models are proposed to address the problem of tooling machining centers in a flexible manufacturing system. In [2], heuristics for routing are proposed when the process plan is tree-shaped (as typical of assembly processes). The model is then generalized in [13], and a large LP model (solved via column generation) is proposed to minimize the total part transfer time.

1.2 SCHEDULING

1.2.1 No-wait Flow Shop

In the no-wait flow shop scheduling problem, there are n jobs, and each must be processed by m machines in series, and no waits are allowed (either on board or in buffers). The high multiplicity case is addressed in [15], in which an approximation algorithm is given yielding a worst-case relative error $(m+1)/2q$ (if $n = qs$).

For $m = 2$, no–wait flow shop is polynomially solvable. However, in some applications the actual value of processing times is not known, but only their relative ranking. In this case, a simple but effective approximation algorithm can be given [89].

1.2.2 Flow shop with limited buffer, 2 machines

In [14, 22] deal with makespan minimization in a 2-machine flow shop with an intermediate buffer of capacity c. The problem has been addressed in the context of batch production, i.e., there are b batches, each consisting of (at least $c + 1$) identical parts, which must be consecutively processed. Although the problem remains NP-hard, there exists [14] a minimum size for each batch such that, if each batch exceeds this value, the problem becomes polynomially solvable (in $O(b \log b)$). In [22] an exact branch and bound algorithm is illustrated to address the general problem, allowing to solve instances with up to 30 batches in a reasonable CPU time. These results are extended to an automated flow shop architecture, using special swapping input/output devices [17].

1.2.3 No–wait Robotic cells

In [23, 27] scheduling problems in *no–wait robotic cells* are addressed, in which part moves among the machines are carried out by a single robot, there are no buffers, and moreover parts cannot wait on the machines. In [23] it is shown that (i) the 2-machine problem can be reduced to a classical 2-machine no–wait flow shop problem, and is hence solvable in $O(n \log n)$; (ii) for $m = 3$ and identical parts, the optimal periodic robot moves can be searched among simple and double robot cycles only. In [27] the complexity of the problem is analyzed for a 3-machine no–wait robotic cell $m = 3$, for each of the 6 possible simple cycles.

1.2.4 Single machine, paced jobs

Given n jobs which are constrained to being released at regular intervals for processing, the problem is to decide their sequencing in order to minimize total completion time, while keeping the machine always busy. In [16] the problem is shown to be NP-hard, and an effective branch and bound algorithm is proposed.

1.2.5 Parallel machine scheduling with deadlines

Given n jobs and m (non identical) parallel machines, the problem is to assign the jobs to the machines so that each job completes within its deadline. Drawing from an application, the problem has been addressed when there are K distinct job lengths. In [26] it is shown that the problem is NP–hard already for $K = 2$, and an effective implicit enumeration algorithm is presented that allows efficient solution of a set of real-life instances.

1.2.6 2-job job shop with nonregular objective

In [24, 29] the problem is analyzed of scheduling the tasks of two jobs, each characterized by a non regular function of its completion time. In [24] the problem of generating all Pareto optimal schedules is addressed, in [29] the problem of minimizing a linear combination of the two objectives.

1.2.7 Sequence coordination between two stages of a supply chain

In two different stages of a supply chain, different jobs require different types of set-up. The problem is to find a common sequence accounting for the different set-up requirements in the two stages. In [30] the problem of minimizing the total number of set-ups has been analyzed. It is shown that it is equivalent to finding the hamiltonian completion number of the line graph of a bipartite graph. The NP-completeness of the problem is proved, and an efficient heuristic approach is proposed. In [28] a special case is discussed, in which the graph describing the problem is a tree; in this case the problem can be solved in linear time.

In [40] it is assumed that each stage has an ideal sequence of jobs, and there is a limited intermediate buffer allowing partial resequencing. The objectives considered include the minimization of storage costs as well as the distance of the two input sequences from the respective ideal sequences.

1.2.8 Scheduling of part programs with set-up costs

In [33, 37] a flexible cell is considered in which one processor can execute part programs. Each operation requires a certain tool, and there is a set-up at each tool change. The problem is to sequence the parts so that the total number of set-ups is minimized, considering that there can be at most k parts currently under process. In [33] it is proved that for $k = 3$ the problem is NP-hard, and a branch-and-price scheme is proposed. For the same problem, a heuristic approach is presented in [37].

1.2.9 Multi-agent scheduling

In [25] some implementation paradigms are discussed for autonomous agents in a production system with several machining centers. These paradigms differ from each other for various level of complexity and the amount of information exchanged by the agents. Extensive comparison have been done via simulation.

The special case in which two agents can cooperate to carry out their tasks has been analyzed in [32], in which the problem of selecting the processes and sequencing them is solved by means of graph theoretic models.

In [35] scheduling problems are considered in which two agents must share common processing resources. Each agent owns a set of jobs, and pursues a certain objective. The complexity of several problem is analyzed, in whichthe objectives include total completion time, number of tardy jobs, and min-max functions. Some results are extended to more than two agents in [41]. In [78, 79] surveys on the main modeling approaches to multi-agent problems are presented. In [46] exact algorithms are reported, based on Lagrangean relaxation, for some special hard cases. In [45] the problem is addressed with the tools of negotiation theory. In particular, the problem is analyzed of defining and computing the Nash bargaining solution. The problem of nonconvex baragining sets is further analyzed in [53].

In [64] a noncooperative game corresponding to a multi-agent project scheduling problem is considered, in which each agent controls a subset of activities, and a pre-defined reward scheme exists as the agents manage to descrease project makespan. The complexity of the problem of finding Nash equilibria with bounded makespan is analyzed.

In [83] the whole body of literature on multiagent scheduling problems is reviewed and presented according to a novel classification scheme. Several unpublished extensions of known results to a more general context are also presented, namely concerning a scenario in which the agents' job sets may not be totally disjoint.

In [66] a situation is considered in which two agents (holding various objective functions) submit their respective jobs in a certain order to an external coordinator who, in turn, selectes one submitted job for processing, according to a rule (which is common knowledge). Various problems are considered, from both viewpoints of the coordinator (determine the set of Pareto optimal schedules compatible with the selection rule adopted) and of single agents (determine a minmax strategy). The complexity of the problems is analyzed.

1.2.10 Scheduling with generalized preemption

In [43] a scheduling problem is studied, arising in the painting department of a kitchen manufacturer. Here the activities can be preempted, but there are some special features taking place every time processing is resumed. For this class of problems, NP-hardness is proved and a time-indexed set-packing formulation is used to derive very effective lower bounds. The problem of generating good bounds is addressed in detail in [49]

1.2.11 Batch selection

Given a set of tasks, each requiring a certain tool set in a tool magazine, the problem is to decide which tools should be mounted in the tool magazine in order to maximize the revenue from tasks which are enabled. A branch and bound is designed allowing to exactly solve realistic-size instances with limited computational effort [36].

1.2.12 Scheduling UMTS

Some scheduling problems arising in UMTS teelcommunication systems have been studied. The problem is to find an allocation of information packets to the time slots of a radio frame. In [34] an exact dynamic programming algorithm is presented for two classes of traffic. In [39, 47] packets of different services are allocated. QoS constraints restrict feasible allocations. The objective is to minimize the overall weight of tardy packets. In [39] a polynomial algorithm is presented for the case of two services and general time windows. In [47] we consider any number of services, each having a deadline.

1.2.13 High-multiplicity bin packing

In the high-multiplicity bin packing problem, only C distinct types of objects exist. When $C = 2$, it is shown that the problem can be solved in $O(\log D)$, where D is the capacity of each bin. An approximation algorithm having the same complexity is given for the general case, providing a solution which always yield at most $C-2$ bins more than the optimal number.[38]

1.2.14 Scheduling unsupervised systems

The problem is to sequence n jobs on m parallel machines, a job having a certain success probability p_i and a revenue r_i [44]. If a job fails, the machine in charge of it is blocked and the remaining jobs on that machine are lost. The objective is to allocate and sequence the jobs in order to maximize expected revenue. The polyhedral structure of the problem is analyzed, and a very simple round robin rule is given, yielding good approximation results. In [55] it is shown that, when $m = 2$, the general list scheduling algorithm yields a worst-case approximation of 0.853. In [68] the model is applied to the special case in which machines are subject to unrecoverable, exponentially distributed interruptions. It is shown that the problem is still NP-hard, and effective solution approaches are presented.

1.2.15 Two parallel machines, three chains and problems with operators

The problem is to execute three chains of tasks on two parallel machines, minimizing makespan. In [48] it is shown that this problem is NP-hard, but there is a fully polynomial time approximation scheme. In [51] the model is extended to consider three jobs in a job shop with two operators. Dynamic programming and branch and bound methods are compared on a computational basis. In [59] a case study in leather manufacturing is analyzed and a general model for job shop problems with human operators is proposed. In [54] a class of problems is analyzed with chain precedence constraints and each task is assigned to a machine, as in a job shop. However, the objective function depends on the completion time of each task. The complexity of the problem is discussed for various objective functions.

1.2.16 Call planning

In [50] a call planning problem is considered, with an application to pharmaceutical marketing. The model plans visits of sales representatives to physicians on the basis of physician's responsiveness and potential market. A heuristic approach is applied to a set of real data.

1.3 Healthcare applications

1.3.1 Resource allocation problems in operating room planning

In [95], the surgical case assignment problem is considered. A model is proposed accounting for the status of the waiting lists and as well as surgeons' availability and other clinical constraints.

In [56] a more general model is applied for operating room planning. For a medium-long-term horizon, the paper analyzes the impact of the variability of the master surgical schedule on some efficiency indices such as due date performance and operating room utilization. The experiments highlight that leaving even a limited amount of flexibility in MSS design can allow significant improvements in operating room balancing and system throughput. A synthesis of this work along with a discussion of the whole lean reengineering process is given in [63] (in Italian).

In [57], a decomposition heuristic approach is applied to the integrated problem of determining MSS and SCAP. In particular, a novel min-cost flow problem is proposed to compute the MSS. The approach can compute very effective solutions in very small computation time.

In [62] a model is presented which integrates daily surgical planning (SCAP) and bed management, in a hospital con la gestione dei posti letto, in a hospital organized by intensity of care.

1.3.2 Patient Flow Management in haematology

In citepolsan a problem of scheduling appointment is described in a haematology department, illustrating the results obtainable through a combinatorial optimization model. The problem is dealt with in [75], where the re-engineering process is discussed and detailed, and the results of the integration between optimization and simulation are provided.

1.3.3 Lean thinking in Healthcare

. In [**?**], the organizational problems in elective surgery are analyzed and the contribution that may come from the application of *lean* methodologies. A practical manual for the preparation of an A3 model is presented in [85]. In [84] we discuss the role of optimization models in lean applications in healthcare and other services. In [73] the application of lean thinking is presented to the scheduling of chemotherapy sessions.

1.3.4 Models for electrical energy management

In[96, 97], decision problems are presented concerning an electical energy aggregator. The aggregator is an intermediate subject between retailers and users. Its aim is to exploit the time flexibility offered by a pool of users to profitably buy/sell energy over time.

In [58], the problem is addressed of scheduling various types (appliances, air conditioning, heaters) of electrical loads in a household, considering three distinct objectives related to costs, comfort and timely execution of daily tasks. A heuristic algorithm is presented, designed to be implemented in a household energy controller ("Energy Box"). A preliminary version of this work is presented in [98].

1.3.5 Production/distribution integration

In [60] decision models are proposed for the integration of production and distribution in a two-stage production plant (*inbound distribution*). The decisions concern job sequencing and batching, in a context in which deadlines at the second stage are related to the times jobs are released at the first. The complexity of various problems is analyzed, for various transportation system structures (i.e., for different transportation modes and amount of vehicles) and for different contractual agreements (sequencing decided by the manufacturer vs. cooperation between the two subjects). In [61] several possible agreement types (concerning constraints on delivery times) are analyzed. The scenarios are compared by means of experiments that allow quantifying the advantages stemming from cooperation between the two subjects. In [65] two algorithms are presented that significantly improve the complexity of the corresponding algorithms presented in [60]. In [69], new models are presented for the case in which holding costs are also taken into account, and the complexity of various special cases is analyzed. In [70] an integrated production/vehicle routing problem is addressed, in which the sequence in which customers are visited is fixed a priori. The complexity of the problem is analyzed and some special cases are addressed.

1.3.6 Capacity expansion problema

In cite chaabane a noncooperative game is considered in which the different agents control various arcs of a network, and there is an expansion cost and compensation if the maximum flow increases. It is shown that finding a Nash equilibrium is an NP-complete problem, but an appropriate primal-dual formulation of the problem allows one to find such equilibrium in reasonable time on realistic-sized instances.

1.4 Location problems

In [8] the problem of locating inspection stations in a flow line is considered. The problem consists of deciding whether or not locate an inspection after each workstation, and to determine the operating mode (scrap or repair the defective part). The complexity of various formulation is studied and solution algorithms are given.

In [10] a problem concerning hazardous material transportation is considered. The problem is how to locate a certain number of control stations on a road network, in order to maximize the number of controlled vehicles and minimize the chances of lethal accidents. Some $\epsilon-$approximation algorithms are presented.

In [31] the problem is to define p police districts on a network. The objective is to minimize the maximum diameter of a district, taking into account traffic workload balancing constraints among the districts. Formulations and solution algorithms are proprosed for $p = 2$ and $p = 3$, for the special case of tree-shaped networks.

In [42] a problem of resource selection and location is considered. Each resource (e.g. radar) has an installation cost and a variable cost which is quadratic with respect to its covering radius. The problem is shown to be NP-hard, and an exact, effective algorithm is given, based on a Lagrangean relaxation of the problem. In [52], the model is generalized to include all those problems in which a unit resource must be allocated to a number of users, the cost consisting of a fixed term and a semiconvex latency function. Problems with hundreds of users, which are unsolved through general-purpose commercial solvers, are solved exactly, exploiting certain feature of the Lagrangean dual.

2 TEACHING

1994–1998 Università di Roma "La Sapienza", School of Engineering, *Industrial Automation* (graduate course)

since 1998 Università di Siena, School of Engineering, *Operations Research* (undergraduate course) and *Optimization models in logistics* (graduate course).

since 1992 Decision modeling courses in several one-year postgraduate programs: Master in Business Administration (LUISS Guido Carli, Roma), GINTS (Università di Siena), CIPMI (Università di Siena), Master in Enterprise Engineering (Università di Roma "Tor Vergata"), Master in Engineering for Public Administration (Università di Roma "Tor Vergata").

since 2005 Head of the PhD program in Information Engineering, Università di Siena.

since 2003 Head of the graduate program in Engineering Management, Università di Siena.

since 2014 Director of the Master Program in Lean Health Care Management, Università di Siena.

3 OTHER ACTIVITIES

3.1 Editorial activity

since 1997 Associate Editor of *IIE Transactions.*

since 2003 Area Editor of *4OR - Quarterly Journal of the Italian, French and Belgian Operations Research Societies.*

since 2010 Associate Editor of *Journal of Scheduling.*

Reviewer for *Operations Research, Management Science, European Journal of Operational Research, International Journal of Flexible Manufacturing Systems, Annals of Operations Research, IEEE Transactions on Robotics and Automation.*

3.2 Projects

1992-1993 Head of the project "Operations management in a plant for car assembly" (with Università di Roma Tor Vergata and FIAT research center).

1998–2001 Head of the project "Decision architectures for a production environment with autonomous agents" (funded by the Italian Ministry of Education).

1999–2002 Head of a research unit in the project "Integrated Logistic systems: design and performance optimization" (funded by CNR).

2000–2002 Head of a research unit in the project "Models and algorithms for planning and scheduling in distributed systems" (funded by the Italian Ministry of Education).

2001–2003 Head of a research unit in the project "Network simulation and optimization: software and applications" (funded by CNR)

2008-2010 Head of a research unit in the project "Coordination strategies and mechanisms in distributed logistic systems" (funded by the Italian Ministry of Education).

2011-2013 Head of the research project "Gestione delle risorse critiche nelle strutture ospedaliere (GERICO)" ("Management of critical resources in hospitals"), funded by the Tuscany Region.

3.3 Organization

2002 He organized the CIRO school for young researchers (Siena, June 2002), editing the proceedings [82].

2005 He was Local Chairman of the 7th MAPSP conference (Models and Algorithms for Planning and Scheduling Problems), June 6–10, 2005.

2009 He was the Scientific Chairman for the 40th AIRO Conference (Siena, September 8–11, 2009.

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