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Project-Team MACSI

Modeling, Analysis and Control of Industrial Systems

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1. Team

Macsi is a team of INRIA-Lorraine. The part of MACSI team located in Nancy belongs to Laboratoire de Recherche en Informatique et ses Applications (LORIA) in common with Centre National de Recherche Scientifique (CNRS), Institut National de Recherche en Informatique et Automatique (INRIA), Université Henri Poincaré (Nancy 1), Université Nancy 2 and Institut National Polytechnique de Lorraine (INPL). The part of MACSI team located in Metz belongs to Laboratoire de Génie Industriel et Production Mécanique (LGIPM) in common with ENIM, ENSAM and University of Metz.

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2. Overall Objectives

2.1. Overall Objectives

MACSI is an INRIA project-team since January 2000, after having been preliminary-project (avant-projet) since January 1998. The objectives of MACSI are design and/or control of Industrial Systems at different decision levels: stategic (organization and dimensioning of virtual enterprises or supply chains), tactical (planning, scheduling, maintenance, transport) and operational (control synthesis).

The main activities of MACSI can be organized along two complementary axes:

- Modeling, specification, design and evaluation of industrial systems, using simulation (descriptive models) and performance evaluation (analytical models) of industrial systems including enterprise modeling (descriptive models), behavior modeling (analytical models), control synthesis and production system design;
- Modeling, simulation, optimization and decision making tools applied to off-line and on-line control of industrial systems including planning, predictive, proactive and reactive scheduling, on-line production control and research of good maintenance policies.

The ”Industrial Systems” we consider can be:

- A network of enterprises (with centralized or partially decentralized command);
- A supply chain which may be divided among several enterprises or networks of enterprises;
- An enterprise;
- A plant;
- A production system;
- A workshop;
- A transport system.

The theoretical bases and tools are those of discrete event systems: DES simulation, Petri nets, time automata, discrete and continuous flow models, queueing systems, multi-agent systems, and discrete optimization: complexity theory, design of exact efficient algorithms, integer linear programming, meta-heuristics, hybrid approaches integrating decomposition approaches.

The aim of our research is resolutely two-fold, by developing on the one hand fundamental research, while being constantly dedicated to solving industrial applications. As often as possible, generic solution approaches are proposed and validated by experiments or proof of analytical results.

Thus, MACSI considers specific problems of organization, of performance evaluation, of planning and scheduling including the search for efficient maintenance policies.

3. Scientific Foundations

3.1. Specification, control synthesis, design and evaluation of industrial systems

Keywords: *Analytical models, control synthesis, design, extended enterprise, modeling, network, optimization, performance evaluation, simulation, specification, supply chain, virtual entreprise.*

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MACSI activities within this topic are mainly dedicated to: modeling, specification, design and performance evaluation of industrial systems, using simulation (descriptive models) and/or optimization (analytical models). They include enterprise modeling (descriptive models), behavior modeling (analytical models), control synthesis and production system design.

3.1.1. Supply chain management

Global economy not only offers new business opportunities for companies but also challenges the companies to optimize their business processes to remain competitive. Competition is not between individual organizations but between competing supply chains [65]. In order to remain competitive in the global market, companies should be reactive to the rapidly changing demand and improve flexibility. Confronted with a highly competitive environment, supply chain management (SCM) is generally referred to as an effective means to help companies reduce costs, to be reactive and so on. Supply chain management is a way to supervise the flow of products and information as they move along the supply chain. The goal is to optimize the supply chain, which can not only reduce inventories, but may also create a higher profit margin for finished goods by giving customers exactly what they want. Apart from its effectiveness, SCM is a complex process because of the stochastic nature and ever-increasing complexity of the supply chain/networks. Hence, there is no generally accepted method by researchers and practitioners for designing and operating a supply chain.

The design and management of supply chains/networks are complicated by the great variety of available policies for each of the decision problems (purchasing, production, warehousing, transportation,...), by the need to assess complex trade-offs between conflicting objectives, and by the requirement of testing the dynamic behavior of the overall system within an environment affected by uncertainty. Furthermore, one has to move smoothly between hierarchical levels, incrementally adding details; for instance, a multi-scale inventory system can be simulated by modeling the transportation delay with random variables. Alternatively, the lead time can be determined by solving a vehicle routing problem (VRP) and explicitly simulating the transportation sub-system.

Lots of deterministic and stochastic supply chain optimization models have been developed in the literature [76], [62]. Simulation has been identified as one of the best means to analyze and deal with presence of stochastic events in supply chain. Its capability of capturing uncertainty, complex system dynamics and large scale systems makes it attractive for supply chain study. It can help in the optimization process by evaluating the impact of alternative decision policies. Therefore, many simulation models have been built to facilitate the use of simulation in designing, evaluating, and optimizing supply chains (IBM Supply Chain Analyzer, Autofat, Supply Chain Guru, Simflex, ...).

At the same time, thanks to several decades of theoretical and pratical developments, state-of-the-art optimization engines such as ILOG-CPLEX and DASH-XPRESS have proven to be able to solve real large size decision making problems of millions of variables and millions of constraints. These optimization engines are now used to power advanced Supply Chain Management tools (I2, Manugistics, Peoplesoft, SAP,...) for solving complex supply chain planning/scheduling problems. Impressive cost reduction and customer satisfaction achievements and success stories are frequently reported by optimization engine providers or by SCM tool providers. The strength of SCM tools resides in their ability to efficiently coordinate activities through the whole supply chain: from demand planning, to procurement, to manufacturing, to inventory control and to distribution. These activities that were optimized locally in the past are now optimized globally through the use of SCM tools. The **weakness of these optimization tools** is the impossibility to take into account random events. All optimization tools are based deterministic on optimization models and the quality of the results strongly depends on the quality of the estimated data such as demand forecasts and the variability of the random quantities.

Simulation-optimization is a subject that has attracted the increasing attention of many researchers and practitioners. Existing literature related to simulation-optimization methods can be classified under four major categories: gradient based search methods, stochastic optimization, response surface methodology and heuristic methods [63]. Heuristic methods are usually preferred over the other three, when dealing with qualitative decision variables.

MACSI's objective is to develop a simulation-optimization methodology for supply chain design problems that selects the strategic decisions (opening and/or closing decisions for network configurations) based on their impact on both qualitative and quantitative supply chain performances. The methodology is composed of three basic modules: a genetic algorithm (GA) optimizer for strategic decision selection, a discrete-event simulation environment (DES) for operational performance evaluation and a supply chain modeling package. The GA optimizer guides the search direction to the near-optimal solution systematically considering the feedback from simulation evaluation. All the candidate network configurations, proposed by the GA optimizer, are evaluated by corresponding simulation models. The simulation models are extended from the supply chain modeling package via object-oriented technology. Appropriate estimation of key performance indicators (KPI) of the supply chain are provided as feedback for guiding the genetic search. Moreover, uncertainties related to demand, production and distribution are taken into account by decision-makers through simulations.

3.1.2. Network of firms

To achieve the expected goals in terms of minimizing the delay of deliveries, the holding costs and the transportation costs, it is imperative that enterprises work together. New forms of organizations have emerged, the so-called extended enterprises and virtual enterprises [72], in which partners must demonstrate strong co-ordination and commitment capabilities to achieve the desired goals. A virtual enterprise (VE) could be a single enterprise or a grouping of similar companies (i.e. similar goods).

Today, in a network of firms, manufacturers no longer produce complete products in isolated facilities. They operate as nodes (i.e. single or virtual enterprise) in a network of suppliers, customers, warehouses and other specialized service functions [67]. To generate a better productivity, these companies need to coordinate the different actions which are distributed among autonomous partners [77], [80], [74]. Due to the high complexity of a whole network of firms, a centralized decisional system seems not be able to manage easily all the necessary information and actions [78]. Moreover, the centralized philosophy is strongly opposed to the decisional autonomy of the supply-chain components (firms). This is why, the MACSI project is working on a more distributed approach in order to provide autonomy and to facilitate the management of a network of firms, while considering a win-win global strategy.

3.1.3. Control synthesis

Production systems are often complex making the realization of an effective and realistic control device more difficult. Several studies were dedicated to Discrete Event Systems (DES) control problems. The objective is to synthesize the suitable supervisor which will act in closed-loop with the process, in order to obtain the desired behavior. The proposed approach by Ramadge and Wonham deals with existence and synthesis of the most permissive supervisors of DES [79]. Indeed, this approach models industrial systems using automata and formal languages. However, the lack of these automata and formal languages limits the possibilities of developing effective algorithms to analyze and synthesis the systems. To mitigate these disadvantages, several control synthesis methods based on Petri nets (PN) were proposed [75], in order to exploit the modeling power of PN and the rich mathematical results which characterize them. This allows us to have a qualitative analysis of the system (attainability, promptness, etc).

MACSI's goal is to propose a new approach for control synthesis of discrete event systems based on marked graphs. This approach allows to solve the forbidden state problems characterized by a set of General Mutual Exclusion Constraints (GMEC) in presence of unobservable transitions.

3.2. Simulation, optimization and decision making tools applied to industrial system control

Keywords: *Discrete optimization*, *maintenance*, *network of firms*, *on line control*, *planning*, *predictive/proactive/reactive scheduling*, *production manufacturing*.

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The organization and the control of any industrial system leads to various optimization problems such as: forecasting, raw material and component supplying, inventory management, planning, scheduling, quality control of the products and the production systems, maintenance policies, etc [71], [83]. The MACSI project focuses on decision making for production systems. Some activities are linked to planning, such as the search for coherent plans within a virtual enterprise or more classical planning research in the presence of limited resources. A lot of the optimization activities within the MACSI project have concerned scheduling problems [81], [68].

3.2.1. Scheduling

Most of the scheduling publications work on very simplified problems very far from the reality of the workshop. We progressively integrate more pertinent constraints for concrete applications in our models. In particular, we have considered simultaneously or separately: calendars on the machine, minimal and maximal time lags between the operations, batching machines, resource blocking. We also consider various workshops: single and parallel machine, flow-shop, hybrid flow-shop, job-shop and even assembly shop with synchronization between the products. Our orientation towards supply chain control provides us also with new models of planning and scheduling integrating negociations related to component arrivals and finished product deliveries. The considered problems are generally NP-hard; in consequence, depending on the problem sizes, we use either exact approaches or approximation approaches in order to solve them in a reasonable computation time while obtaining near optimal solutions. We hybridize different approaches in order to be as efficient as possible: construction approaches, meta-heuristic such as simulated annealing or genetic algorithm and decomposition approaches. A main difficulty consists in building efficient lower and upper bounds in order to improve the methods and/or to evaluate the quality of the proposed methods. Other important research activities consist in getting new complexity results or new dominant properties.

An example of concrete scheduling models concerns batching machines. In this context, the principal motivation to process jobs in batches is to reduce the time and the cost incurred by performing the jobs including product transportation. For any type of batch, the machine is set up for each family of jobs and subsets of products or batches are put on the machine and picked up jointly. It is a sum-batch, when each product is dealed successively by the machine and it is a max-batch, when all products are treated simultaneously by the machine and the batch processing time is equal to the greatest needed processing time. Good examples can be found in chemical processes and particularly in tyre plants.

Another example of concrete scheduling models concerns scheduling with minimal and maximal time lags. This arises as soon as the interval time between to consecutive operations is upper bounded (perishable or unstable products) or lower bounded (cooling or transportation). An important sub-family consists of considering no-wait scheduling problems in which a product must be moved on the following machine and the corresponding operation must begin as soon as the operation is finished on the first machine, with potential separate setup times (before arrival of the product) or removal times on the machine (after departure of the product).

Another important part of our research is linked to scheduling in the presence of disturbances. We have been working for several years on this subject and we are members of research groups working on creating robustness, stability and/or flexibility in the scheduling process (off line and on line control). Our main approach consists in defining new structures, by proposing to the workshop a family of schedules instead of a single schedule. The family is built by an interactive multi-criteria proactive procedure. The flexibility introduced in the family is then used by the reactive on line procedure, which makes standard decision in absence of disturbances and reacts to small and medium disturbances; it orders a re-scheduling when the pro-active schedule can no more be followed without an important performance decrease.

Another activity concerns Capacitated Arc Routing Problems (CARP) in which client arcs in a network must be visited for pickup or delivery. Compared to node routing problems, the CARP has been neglected for a long time by researchers. Fortunately, it has raised a growing interest in the two last decades, mainly because of its important applications like urban waste collection, winter gritting and inspection of power lines. However, the CARP found in literature is not sophisticated enough to handle real-life applications. Our research proposes new problems which integrate more realistic constraints generalizing the CARP. MACSI's objective is to study the flexibility of the CARP in presence of disturbance to integrate more and more pertinent constraints. In this direction, we have a promising industrial application with BT Exact (British Telecom), including the tactical level.

3.2.2. Planning inside enterprise network

The management of network of firms needs to integrate two decision levels: planning and control. At the planning level, a supply chain, coherent planning of all actors is needed [69], [64]. This integration not only applies to the material flows from raw material suppliers to finished product delivery, but also to the financial flows and information flows from the market (i.e. the anonymous consumers) back to the supply-chain partners. This planning function lies at the tactical level of the network of firms. Control function has a shorter run decision and a smaller focus than planning. Its objectives are restricted on one single or virtual enterprise. It lies at the operational level.

The MACSI project tries to propose a new approach, for the network of firms and the supply chain management, based on the virtual enterprise paradigm and the use of multi-agent concept. The virtual enterprise is defined as a grouping of nodes (or entities) which are linked together with information and material flows. Of course, each node could be itself a virtual or simple enterprise. This work integrated a part of the work made during the V-CHAIN project.

4. Application Domains

4.1. Application Domains

The application areas of MACSI mainly concern discrete production systems (mechanical production, assembly lines, semiconductors fabrication, etc.). Some studies also cover continuous production systems (in particular iron and steel industry), unit or batched systems. Although the main results obtained in the project were studied within the framework of production of goods, most results can be applied to the service industry (enterprise modeling, performance evaluation, scheduling). The competences of MACSI members cover primarily:

1. production systems design going from the formalized requirements, functional, structural and informational aspects, resources and system layout identification and selection, management policy selection, until the simulation and prediction of the system performances;
2. reorganization of existing systems and their performance evaluation;
3. workshop physical flow and scheduling optimization with or without integration of optimized maintenance policy of the equipment;

4. definition and installation of workshop control systems which can react to the different operation risks at various decision levels;
5. production systems integration using integration platforms.

The industrial sectors in which MACSI members are solicited or for which they develop their research concern:

- car industry (FIAT-Italy and Ford-Spain),
- textile industry (HiTec Italy),
- mechanical fabrication (in particular, car equipments manufactures),
- assembly lines scheduling and load balancing (Aprilia-Italy),
- semiconductors manufacture,
- iron and steel industry,
- pharmaceutical and agro-alimentary industries, tyre plants...

MACSI's industrial activities are increasingly related to the design and management of supply chain. They consist in proposing models covering information, material and decision flows respectively, and including several companies working in collaboration to realize some products.

5. New Results

5.1. Specification, control synthesis, design and evaluation of industrial systems

Keywords: *Analytical models*, *control synthesis*, *design*, *extended enterprise*, *modeling*, *network*, *optimization*, *performance evaluation*, *simulation*, *specification*, *supply chain*, *virtual entreprise*.

5.1.1. Production-distribution network design using simulation-based optimization

Participants: Hongwei Ding, Lyès Benyoucef, Xiaolan Xie.

A simulation-based multiobjective optimization method is developed in this study for production-distribution network design. Directed by a multi-objective genetic algorithm, the optimization method searches best solutions both for network configuration design and network operation policies. Candidate solutions encountered during the search are evaluated via discrete-event simulation. A flexible simulation framework is developed that enables automatic simulation of various production-distribution network configurations. The optimization method is applied to a case study from automotive industry. A set of Pareto-optimal solutions is obtained, including decisions related to facility open or close, production order splitting ratios and inventory control policies.

As perspectives, more supply chain facilities are to be defined and implemented. Most importantly, a more comprehensive supply chain simulation framework should be established in order to apply the method for more cases. Some benchmarking works are also to be done for method performance assessment, comparing to the results obtained by analytical methods for some simplified cases [51] [52] [8] [21].

5.1.2. Supervisory control

Participants: Zied Achour, Nidhal Rezg, Alexandru Sava, Xiaolan Xie.

Firstly the supervisory control of untimed Petri net is considered. Given a bounded Petri net model of the plant totally observable or not, the method proposed in this paper computes a Petri net model which corresponds to the behavior of the closed loop system. The controller design is subject to constraints including liveness requirement, maximally permissiveness with respect to given system specifications, and the presence of uncontrollable and/or unobservable transitions. The uncontrollable transitions represent events that cannot be prevented from occurring by a supervisor. Specifications that can be enforced by our approach are expressed as forbidden states (FSP) and/or Forbidden State-Transition Problems (FSTP) and Forbidden state-transitions time depending and so called Time Floating General Mutual Exclusion Constraints (TFGMEC). The proposed approach can be considered as a combination of the Ramadge-Wonham's approach [79] and the theory of regions. It first determines the automaton model of the closed loop system using a Ramadge-Wonham-like approach. It then uses the theory of regions to design the Petri net controller [70], which is a set of control places, whenever a Petri net controller exists. Control places may be with or without self-loops. They are called respectively pure and impure places. Necessary and sufficient conditions for the existence of such solution are established using the theory of regions for the DES totally and partially observable. It is shown through examples that there exist control problems that cannot be solved by adding pure control places. Indeed, impure control places have self-loops with controlled transitions which grant them with a higher power of control [18], [17], [44].

Then, we study the case of the supervisory control with timed constraints. The complexity of discrete event systems (DES) makes more difficult the realization of an effective and realistic control device. Bounded Petri nets are used for modelling DES, hereafter also referred to as plants. For a discrete model of a plant and a set of specifications, the goal of control synthesis is to determine a supervisor represented by a given set of legal markings which guarantees the desired behaviour. Supervisory control allows the avoidance of a set of forbidden states defined by some General Mutual Exclusion Constraints (GMEC) by adding some control places. Consideration of time is crucial for realistic characterization of systems and hence leads to two types of concerns: the checking or validation of certain temporal specifications, and the control which requires temporal specifications. It is therefore important to integrate time in the specifications and synthesis. For this purpose, we introduce a new class of General Mutual Exclusion Constraints (GMEC) called Time Floating General Mutual Exclusion Constraints (TFGMEC), for which we propose a solution method inspired by a supervisor modelled by control places added to the initial Petri net model [50], [1].

Finally, we study the case of the supervisory control of timed Petri net. We propose in this work an approach which deals with the forbidden state problem for time discrete event systems. The dynamic of a TDES is driven by the occurrence of events within given time intervals. Two kinds of events are considered: controllable and uncontrollable. We chose to consider a discrete time. Thus, the elapsing of time is modelled by a special event t. As time cannot be stopped, this event cannot be forbidden or delayed by the controller. However, it can be preempted by forcing the occurrence of a controllable event. The aim is to build a most permissive live controller which guarantees the respect of the given specifications. The most permissiveness property defines the ability of the controller to restrict the least possible the behavior the system. Liveness is the property of the controller to avoid deadlocks. The controller has the ability to 1) fix the arriving moment within the given time interval or 2) to forbid the occurrence of a controllable event. It can' not act neither on uncontrollable events nor on time. The control synthesis technique that we introduce in this paper is based on Time Controlled Petri Net based model. This tool is derived from the Controlled Petri Net model by including a new time firing condition. Each transition of the Time Controlled Petri net model (TCPN) is characterised by a firing condition made of two parts: a time constraint and a logic constraint. The time constraint is represented by a union of time intervals. The logic constraint is a control function. An enabled transition can be fired if both time constraint and logic constraint are satisfied. Consequently, the controller can force or delay the firing of a controllable transition by modifying the time constraint and completely forbid the firing of a controllable transition by acting on the logic constraint. The synthesis of the controller consists in building the state space generated by the evolution of the system and computing new time constraints and new logic constraints such that the forbidden states are no longer reachable and the controlled system is deadlock free.

5.2. Simulation, optimization and decision making tools applied to industrial system control

Keywords: *Discrete optimization, maintenance, network of firms, on line control, planning, predictive/proactive/reactive scheduling, production manufacturing.*

5.2.1. Performance evaluation and stochastic optimization of manufacturing systems

Participants: Sophie Hennequin, Jie Li, Iyad Mourani, Alexandru Sava, Xiaolan Xie.

For the performance evaluation, we firstly study analytically the impact of transportation delays on the performance of single-product continuous flow production lines of two machines separated by one buffer. The machines are subject to operation-dependent failure, i.e. a machine cannot fail if it is not working on a part. Volume to failure and machine repair times are exponentially distributed random variables. We prove that the high the delays, the less the throughput of the transfer line [59].

In a second work, we consider transportation delays in continuous manufacturing system composed of N machines and N-1 buffers. The machines could have time dependent failures (machines can only fail when they are working). We simulate the productivity of manufacturing system with transportation delays. The simulation is based on an original Petri net and shows that the productivity decreases as the delays increase [39], [38].

Concerning the stochastic optimization, our research work focuses on analysis and optimization of production-distribution systems made up by an end-user warehouse supplied by a network of inventories and production facilities. Customer orders arrive randomly at the warehouse, with random order size and the production capacity is finite. The inventory at the warehouse is controlled by a base-stock policy. Each production capacity has a finite capacity and the transportation time between a plant and a warehouse is constant. At first we have considered the case of a two levels production-distribution system, composed of a warehouse supplied by a plant. In [35] we propose an analitical method based on queueing theory for estimating the end-customer service level, the order-to-delivery lead time of the warehouse, the total inventory on order and the inventory holding and backlogging cost. A gradient method is used to optimize the total inventory cost. Numerical comparisons with simulation show that the analytical approach is very efficient.

Furthermore, we extended our research to multiechelon production-distribution systems. These production-distribution systems are characterised by a network of inventories and production facilities.

We provide a new Convergent Optimization via Most-Promising-Area Stochastic Search (COMPASS) algorithm called COMPASS* which improves the original COMPASS proposed in [73]. The algorithm that we propose deals with problems where the performance measure is estimated via a stochastic, discrete-event simulation, and the decision variables are integer ordered. This method is based on random search and on a new neighbourhood structure called most promising area. We prove that the property of convergence to a set of local optimal solutions is satisfied for assumptions which are much more permissive that in the case of the original COMPASS. Consequently, our algorithm is more computationally efficient and converges faster to a local optimum. We applied this method to optimize the global inventory cost of our multi-stage production-distribution system mentioned above. Numerical results validate the COMPASS* method and show that it converge efficiently to a local optimal solution. This approach has also been applied to (R,nQ) inventory policy. We have also solved the case where the constraints imposed to the production-distribution system are estimated via simulation.

Our further research directions concerns the extension of these algorithms to other inventory policies.

Finally, we consider first a continuous-flow model of a single machine with delay. We assume that the machine failure and repair are subject to a general distribution and the demand is constant. The machine is subject to time-dependent failure. Material flows continuously from outside the system to the first machine, and then waits a period of time called delay t for material transfer, before arriving to the buffer. The goal of this work is to find, by using IPA technique, the optimal buffer level (Hedging point), which minimizes the long run average cost [40]. Then, we applied the same IPA method to optimize continuous-flow model of failure-prone production lines with delays composed of N machines subject to time-dependant failures and N-1 buffers. Times to failure and times to repair are also generally distributed and the demand is constant.

5.2.2. Maintenance policy of manufacturing systems

Participants: Anis Chelbi, Sofiene Dellagi, Michael Fu, Mohamed Salah Ouali, Nidhal Rezg, Xiaolan Xie.

We established in this work a new preventive maintenance approach for manufacturing systems which inflated by the environment constraint. The manufacturing system under consideration is composed of a machine M1 which produces a single product. To satisfy a constant demand d exceeding the capacity of M1, the system uses a subcontractor composed of a machine M2 which produces at a certain rate the same type of product. Both machines are subject to random failures. Machine M2, which constitutes the environment and outside the system, has a constant failure rate and its failures cannot be prevented by preventive maintenance. Machine M1 has a failure rate that is increasing with its age and its failures can be prevented by preventive maintenance actions. An age-limit policy is used for preventive maintenance planning and machine M1 stops for preventive maintenance when it reaches a given age m. In fact we noted by SMP a simple maintenance policy. In this policy we fixed a preventive maintenance age m which depends only on the history of machine M1. After that we established another policy notes IMP, the improved maintenance policy which depends on the history of machine M1 and the state of its environment the machine M2. Precisely when the preventive maintenance age m established in the first policy SMP coincide with a reparation period of the machine M2, we delay this age m to another age $m + \frac{1}{2}m$ in order to decrease a demand loss. To justify this idea we compared the two policies in term of maintenance and demand loss cost, and we proved analytically that under some conditions related to the data of machines M1 and M2, the IMP policy is more economic then the SMP policy. More then the best choice of the delay period $\frac{1}{2}m$ can assure a best profit in using IMP policy. Numerical examples are used, to prove the impact of the IMP in terms of a performance measure and confirm its usefulness [7], [6], [15], [23] and [22].

In another research work developed in collaboration with Michael Fu (University of Maryland), similar problems are modelled with Markovian Decision Process (MDP). Under restrictive technical conditions, some dominant properties were proved and used for a numerical resolution. The perturbation analysis technique was also applied to a production line under the hypothesis that the maintenance policy and the inventory policy are known. An approximation analytical approach using simulation was also developed. This method is good when the machine load is small but is deceiving when the machine load increases, while the perturbation based method gives optimal solution in a reasonable computation time.

5.2.3. Predictive scheduling problems for manufacturing systems

Participants: Henri Amet, Freddy Deppner, Gerd Finke, Julien Fondrevelle, Aimé Kamgaing Kuiteing, Mikhail Kovalyov, Ammar Oulamara, Marie-Claude Portmann.

Scheduling problems with minimal and maximal time lags

We study permutation flowshop problems with minimal and/or maximal time lags [2], where the time lags are defined between couples of successive operations of jobs. Such constraints may be used to model various industrial situations (food production, pharmaceutical, iron industries, etc.). A generic approach based on an exact branch and bound procedure was first developed. We propose several extensions, for which our method is still valid [25], [26]. Since job release dates and delivery times may be modelled using minimal time lags, our procedure can integrate these additional constraints. Moreover, we show that general time lags defined between any couple of operations of jobs can also be taken into account. Finally, we consider the restricted problem, which consists in building the best schedule with respect to a given job sequence on the first machine, it is proved to be NP-hard in the strong sense, if we do not restrict the search to permutation schedules [27]. We introduce a new criterion related to resource utilization: the weighted sum of machine completion times [27]. This objective function generalizes makespan and we give several complexity results for flowshop problems with time lags. Besides we extend our exact approach to solve the corresponding m-machine permutation case. We also address the minimization of maximum lateness on a m-machine permutation flowshop with exact time lags [53]. We study polynomial special cases and propose to apply our generic approach to solve the general case, which is strongly NP-hard even for two machines. We extend a dominance condition and develop a specific lower bound. The obtained solution method outperforms a previous one proposed for the two-machine no-wait flowshop with non sequence-dependent setup and removal times [10].

No-wait ring flowshop

This work was developed in collaboration with Johan Cohen and Stephan Rousseau. The scheduling problem we consider is related to the exchanges of messages between computers through an optical ring-shaped network (European projects DAVID and METEORE). It can be modeled as a particular no-wait job shop (called here ring no-wait flow shop) or as a general multi-processor system scheduling problem or as a specific 2-D cutting problem. It is NP-Hard in the strong sense. We tested several approximation approaches. One approach uses a temporal decomposition in which any sub problem is solved exactly using an integer linear programming package. A second approach uses a genetic algorithm improved by automatic selection of the genetic operators. Both approaches are compared on families of a generated benchmark. This permits us to improve both approaches, when they are systematically the worst for a particular instance family [19] [43].

No-wait flowshop with parallel batching machines

We study a problem of scheduling n jobs in a no-wait flow shop consisting of m batching machines. There is no intermediate buffer between any pair of machines. Batching machines can process several jobs simultaneously in a batch so that all jobs of the same batch start and complete together. We assume that the capacity of any batch is unbounded. The objective is to minimize the makespan. For m=2, the problem is polynomial with schedules of at most two batches. For m=3, the number of batches can be limited by 9 and we propose a 3-, 2- and 3/2-approximate solutions [13] [24].

No-wait flowshop with parallel and serial batching machines

We consider a no-wait flowshop scheduling problem with two batching machines. The first batching machine is *max-batch* machine, it treats several tasks simultaneously. The capacities of batches on this machine is bounded by some integer value b ($b < n$). The second machine is *sum-batch* machine, it treats several tasks sequentially. A setup time is required on such machine before each execution of a batch. The batches are processed in a no-wait fashion. We show that the makespan minimization is NP-Hard in the strong sense and we present an heuristic to minimize makespan with guaranteed performance factor of 2. Also we study two particular cases: (i) all tasks have the same processing times on the first machine and (ii) all tasks have the same processing times on the second machine [41] [14].

Flowshop scheduling problem with batching machine and task compatibilities

The motivation comes from processing products in tires manufacturing industry. The main part of production system (building and curing) can be modelled as a scheduling flowshop with two machines. The processing time on machine two is given by an interval. The first machine is can process no more than one task at time. The second machine is a max-batch machine with capacity k. The tasks of the same batch have to be compatible. We show that the makespan minimization is NP-Hard in the strong sense and we present a branch and bound algorithm and heuristics approaches [56].

Cooperation in supply chain scheduling : minimizing the inventory holding cost and delivery cost

We consider a scheduling problem in a supply chain in which several suppliers are cooperating to ensure the production of one or several types of products in quantities satisfying the needs of the clients. The client asks for a fixed and well known quantity of each type of product that he needs. The products are batched together for delivering to the costumer. The objective is to minimise the overall inventory holding costs and the delivery costs. Other various previous or more recent optimization works have resulted in some publications [11] [60] [49].

5.2.4. Flexible approaches for planning and scheduling in presence of disturbances

Participants: Mohamed Ali Aloulou, Mais Haj-Rachid, Mikhail Kovalyov, Zerouk Mouloua, Ammar Oulamara, Marie-Claude Portmann, Wahiba Ramdane Cherif.

Concerning flexibility in scheduling approaches, we addressed shop scheduling problems with the presence of perturbations. The tasks are characterized by due dates and some precedence constraints. In such a context, a good solution to this problem may rapidly become unfeasible. For this reason, it is more interesting to provide the decision maker with a set of solutions having an a priori known quality and offering some flexibility to adapt the scheduling in presence of perturbations. We worked on this subject the previous years and some publications appeared in 2005 [4] [5].

In order to reduce the gap between academic transportation models and complex real applications, we study several extensions of routing problems. Temporal and stochastic extensions of arc routing problems were investigated in [9] and [12]. In this direction, we collaborated with BT Exact (British Telecom). In preliminary study, we worked on vehicle routing of the personnel of BT that must visit customers to perform a given task (installations, maintenance, repair, inspection, ...). The model studied includes realistic constraints like time windows, work priorities, break for lunch and skills. A hierarchical and temporal decomposition approach was proposed, which proceeds in two steps [37] : week-day optimisation to balance the work load of the personnel over the week and manpower assignment to tasks, using a genetic algorithm to solve the resulting Multi-Depot Travelling Salesmen Problem with Time Windows. We are currently working on including uncertainties and dynamics aspects in our models in order to build robust/flexible routing problems able to react to change.

Another extension concerns the coordination of delivery routing and production, in the framework of stable demands and when production costs and transportation costs have the same importance. We investigated in [54] a generalisation of routing problems including production constraints (production and storage capacity, production costs), generally not taken into account in the literature. We studied a basic model (only one plant and one product). The objective was to determine, for each period, the amount produced and the delivery trips, in order to minimize the total cost of production and distribution over the whole horizon. A greedy heuristic was proposed and tested on randomly generated instances.

5.2.5. Supply chain and negociated coherent plans

Participants: Didier Anciaux, Latifa Ouzizi, Thibaud Monteiro, Marie-Claude Portmann, Daniel Roy, François Vernadat.

In the framework of the V-chain Groth European project, we proposed a semi-decentralized architecture for building coherent plans in a network of enterprises. We consider a virtual enterprise (VE) as defined in the V-chain project. The partners of the VE, referred to as nodes of the VE (NEV), use negotiation and mediation principles to collaboratively elaborate consistent production plans. The proposed architecture of the VE is a set of level corresponding to production cycles of products to be delivered by the VE to the customers. A multi-agent system is used to model the behavior of the VE. For each level, a negotiator agent negotiates with NEV's of the same level. Each NEV is able to elaborate direct and backward planning, taking into account variation of demands and forecasts to guarantee a global benefit of the virtual enterprise. The development of decision tools for helping the negotiator agent of each level generates interesting problems. These new optimization problems have now to be solved either by using integer linear programming solver (for problem of small and medium size) or by developing new specific approximation algorithms [33], [34], [58]. SMA architecture developed in MACSI team for reactive system control can be used as support for this approach. We consider a virtual enterprise (VE), where the various enterprise members cooperate in order to provide external customers with finished products. They apply a global win-win strategy. We assume the enterprises can be ranked on a succession of levels: rank 1 for the tier nearest from the customers, rank 2 for their suppliers etc. Using a multi-agents semi-distributed architecture we proposed models and decision tools to be used by the agents in order to ensure a semi-distributed control as efficient as possible. These works concern the negotiation of the forecasted production plans at the tactical level [42], [3]. A distributed informational system was proposed [66]. Models including transportation problem and simulation had been developed also [20], [16], [57], [36], [82].

5.2.6. An efficient Lagrangian relaxation approach for a stochastic inventory-location problem

Participants: Guy-Aimé Tanonkou, Lyès Benyoucef, Xiaolan Xie.

In this study, we developed an efficient Lagrangian relaxation approach to solve a stochastic inventory-location problem. The problem is to design a stochastic distribution network in which a single supplier ships products (single product type) to a set of retailers via a set of distribution centers that are to be located. Each distribution center serves a set of retailers with random demands. The number and location of the distribution centers are not known a priori. They are chosen from a set of retailer locations. The central issues of the problem are: how many and which retailer locations should be selected as the distribution centers, how to assign retailers to the distribution centers, and how to manage the inventory at each distribution center. The goal is to minimize the total location, shipment, and inventory costs, while ensuring a specified retailer service level. Some computational experiments are realized and analyzed which show the effectiveness of the proposed approach [46], [45], [48], [47], [61].

5.2.7. A stochastic programming model for distribution network design

Participants: Guy-Aimé Tanonkou, Lyès Benyoucef, Xiaolan Xie.

This study deals with a facility location problem where decisions must be made in the presence of uncertainties. The problem is to determine the optimal location of distribution centers DCs and allocation of retailers to DCs in a supply chain network. The model is formulated as a two stage stochastic programming model and our solution methodology integrates a recently proposed sampling strategy, the sample average approximation (SAA) scheme, with an accelerated Lagrangian relaxation algorithm to quickly compute high quality solutions to large-scale stochastic supply chain design problems with a modest number of scenarios for the uncertain problem parameters. The objective of this study is to choose the first-stage variables in a way that the sum of the first stage cost and the expected value of the random second-stage cost is minimized. To validate the quality of a candidate optimal solution, computational experiments are realized.

5.2.8. Winner determination in discount auctions

Participants: Kameshwaran Sampath, Lyès Benyoucef, Xiaolan Xie.

Discount auctions is a market mechanism for buying heterogeneous items in a single auction. The bidders are suppliers and a bid consists of individual cost for each of the items and a non-decreasing discount function defined over the number of items. The winner determination problem faced by the buyer is to determine the winning suppliers and their corresponding winning items. We show that this problem is *NP*-hard upon reduction from the set-covering problem. The problem has an embedded network structure, which is exploited to develop heuristics and an exact branch and bound algorithm. Computational experiments were performed to evaluate the proposed algorithms [32], [31], [30] and [55].

5.2.9. Winner determination in combinatorial auctions with interval bids

Participants: Kameshwaran Sampath, Lyès Benyoucef.

Combinatorial auctions, in which bidders submit bids for bundles or subsets of items, have been found to optimize various e-commerce and supply chain business processes. In this paper, we consider a special case of combinatorial auctions, which allows only interval bids, i.e. for a set of consecutive items. The winner determination problem for this bid structure with the OR bidding language (any number of winning bids for a bidder) is known to be solvable in polynomial time using dynamic programming. However, with the XOR bidding language (at most one winning bid for a bidder), the problem is NP-hard. We propose a branch-and-bound framework that uses the dynamic programming algorithm for the OR version as the bounding technique [29] and [28].

6. Contracts and Grants with Industry

6.1. Scheduling and Vehicle Routing Personnel with British Telecom

Participants: Zerouk Mouloua, Ammar Oulamara, Marie-Claude Portmann, Wahibal Ramdane Cherif.

This collaboration began with a master subject: scheduling and vehicle routing of the personnel of British Telecom. We first improved the current decision tools by introducing decomposition decision levels and better heuristics approaches. The main objective is to introduce flexibility inside the tools in order to react rapidly to perturbations. We will continue this work within the perspective of a 'CIFRE' allocation for a new PhD student or another type of industrial contract.

6.2. European projects

6.2.1. French-German project GRailChem

Participants: Lyès Benyoucef, Radu-Constantin Vlad, Xiaolan Xie.

GRailChem is a french-german project, 'Green Rail Freight Transport for Chemical Goods', starting in November 2004.

The aim of this project is to improve the competitiveness and the attractiveness of railway freight transport and thereby resulting in a possible shift in freight transport from road to rail. On one hand the use of innovative information and communication technology solutions (ICT) will serve for this purpose, on the other hand the integration of the obtained information in the organisational process of consignors, transport service providers as well as in public administration and emergency and rescue organisations respectively, whilst developing new optimisation and improvement potentials simultaneously.

Partners: INRIA (F), Log-o-Rail (F), European Oxo GmbH (D), LII Europe (D), Nacco (F), ELTA (F), OHB (D), Timtec (D), BIBA (D).

6.2.2. Network of Excellence IPROMS

Participants: Zied Achour, Lyès Benyoucef, Sophie Hennequin, Jie Li, Iyad Mourani, Nidhal Rezg, Alexandru Sava, Guy-Aimé Tanonkou, Xiaolan Xie.

The Network of Excellence for Innovative Production Machines and Systems (IPROMS, starting in October 2004), funded by the EU's FP6 Programme, will address the area of production research in an integrated manner in order to reshape the area and overcome its current fragmentation. I*PROMS will develop concepts, tools and techniques enabling the creation and operation of flexible, re-configurable, fault-tolerant and eco- and user-friendly production systems that can react to customer needs, environmental requirements, design inputs, and material / process / labor availability to manufacture high quality, cost-effective products. At present, I*PROMS comprises 30 member institutions representing 14 European countries. They will commit 139 research staffs and 71 PhD students to prosecuting the joint programme of activities developed by the Network. I*PROMS is organized into five clusters: APM (Advanced Production Machines), PAC (Production Automation and Control), IDT (Innovative Design Technology), and POM (Production Organisation and Management). Our team participates to clusters PAC and POM.

7. Other Grants and Activities

7.1. Regional actions

7.1.1. QSL action: Software for reliable control synthesis of Event Discrete Systems

Participants: Nidhal Rezg, Alexandru Sava, Xiaolan Xie.

The QSL (Qualité et Sureté Logicielle) project relates to the software development to integrate the various methods of synthesis in the control field developed by team MACSI of the INRIA Lorraine. The synthesis methods allow the determination of an optimal controller by taking into account uncontrollable and unobservable events of Discrete Events Systems (DES). An effort will be devoted in this project to the development of methods of synthesis integrating the temporal aspect and fault tolerance aspect in DES (sure controllers).

7.2. International activities

7.2.1. RM "Reliability and Maintenance" Network

Partners of the RM network, the University of Laval (Canada), the Polytechnic School of Montreal (Canada), the Higher School of Science and Technology of Tunis (Tunisia) and MACSI, exchange their industrial and scientific experiences and results on reliability and maintenance of production systems.

7.2.2. Collaboration with Canada

We have been collaborated with Wieslaw Kubiak, professor at the Memorial University of Newfoundland (St John's). After his visit of two months last year as invited professor at the École des Mines de Nancy, Ammar Oulamara spent one month and Marie-Claude Portmann two weeks in August 2005 at the Memorial University. Themes: max and sum batch scheduling and just-in-time scheduling in the framework of the supply chain.

7.2.3. Collaboration with USA

Members of our team collaborate with Georgia Tech, Atlanta, on the problem of Optimization of Discrete Event Systems.

7.2.4. Collaboration with Belarus

More and more collaborations have been developed with researchers from Belarus (Minsk). The schedulers of MACSI are Foreign Collaborators of the ISTC Project B-986 "Models, methods and tools for decision support of designing and scheduling for the engineering systems with parallel and series structures". After numerous invitations of Belarus colleagues in Metz and Nancy during the last five years (Mikhail Kovalyov, Yuri Sotskov, Yakov Shafransky, Valery Gordon), Ammar Oulamara and Marie-Claude Portmann were in Minsk during the conference ECCO in May 2005. They remained some days more to develop research and forecasted new collaborations and visits. Themes: Scheduling, line balancing, design and scheduling for parallel and series structures.

7.2.5. Collaboration with China

We collaborate with Shangai Jiao Tong University on scheduling and real time control of FMS using Petri nets (French-Chinese Avanced Project PRA submitted demand), with University of Sciences and Technology of Hongkong on the utilization of optimization-simulation approaches for design and optimization of supply chain (project PROCORE submitted demand) and with Hong kong Polytechnic University on batch Scheduling in supply chain (submission of a PROCORE project).

7.2.6. Collaboration with Taiwan

We collaborate with National Taiwan Ocean University on the theme of modeling and evaluation of VLSI manufacturing systems using Petri Net.

8. Dissemination

8.1. Scientific community animation

8.1.1. Action for the research community

The collaboration, initiated last year between MACSI and ALGORILLE, on a particular token ring scheduling problem issued from ALGORILLE works leads us to competition. This problem has been modelled and solved by many different approaches coming from the different backgrounds (2D cutting or no-wait scheduling approaches as special case of schedules with minimal and maximal time lags or decomposition approaches crossed with integer linear programming). The approaches have been intensively experimented.

The industrial engineering club has vocation to federate the community of the researchers in industrial engineering, by extremely interdisciplinary nature. Frequently, MACSI members take part in the activities and meetings of the club.

Many members of the team have participated in the "Club Génie Industriel". Many members of the team are members of the ROADEF (French Operations Research Society). Thibaud Monteiro is member of the board of directors and manages the pedagogical commission. Xiaolan Xie is member of the committee of the French Group of Petri Net. Many members of the team have participated to the GDR MACS pole STP. Mainly, in the following two groups: GT OGP (organization and production management) and GISEH (management and engineering of hospital systems). Nidhal Rezg is a co-animator of the group INCOS of the GDR MACS. Marie-Claude Portmann was invited guest for a plenary session of the GDR MACS in Clermont Ferrand. Marie-Claude Portmann is a member of the recently created *Comité d'expert "productique" du CNRS*.

8.1.2. Member of organizing committees

MACSI members were involved in many scientific and organizing conferences committees.

Ammar Oulamara and Marie-Claude Portmann as guest editors received 48 papers for a special issue of the European Journal of Operational Research dedicated to PMS 2004.

8.1.3. Member of program committees of journals or conferences

Members of the team participated to the scientific committee of the following conferences:

- ROADEF 2005 in Tours, ORP3 (Operational Research Peripatetic Post-graduate Programme) 2005 in Valencia, Génie Industriel in Besançon, JDMACS 2005 in Lyon. (Marie-Claude Portmann)
- MSR2005, Autrans, France, 2005. (Xiaolan Xie)
- PENTOM (Performances et Nouvelles Technologies en Maintenance), Maroc, 2005. (Xiaolan Xie)

Members of the team were reviewers for the following journals: IEEE Transactions on Automatic Control, IEEE Transactions on Robotics and Automation, IEEE Systems, Man and Cybernetics, IJPR, JESA,DMTCS, EJOR, Journal of Scheduling, COR IJCIM, IJMA, IJPE, JDS, JIM, JIMAD, JORS, RIA, TSI, OMEGA.

Members of the team are editor of special issues of Journals:

- N. Rezg and X.-L. Xie for the special issue on modeling, analysis and control of reactive systems,
- M.D. Jeng and X.L. Xie for the special issue on discrete event system techniques for CIM, International Journal of Production Research, to appear.

Xiaolan Xie is associate editor for IEEE Transactions on Robotics and Automation.

8.2. Teaching

The location of the teaching is linked to the bi-localization of the MACSI team. On one hand, teaching activities are located at the University of Metz (UFR MIM and UFR ESM) and in two independent Engineers schools : École Nationale d'Ingénieurs de Metz (ENIM) and École Nationale Supérieure d'Arts et Métiers de Metz (ENSAM).

On the other hand, teaching activities are located in Nancy, either at the Institut National Polytechnique de Lorraine (INPL), mostly at the École des Mines de Nancy (ENSMN), Industrial Engineering department and at the University Henri Poincaré of Nancy, mostly at the UFR STMIA (Sciences Faculty) or at the École Supérieur d'Informatique et d'Applications de Lorraine (ESIAL).

They are also involved in several professional and research masters. Henri Amet is responsible of the major of the École des Mines de Nancy called "Decision and Production System Engineering".

Ammar Oulamara is responsible of the Mastère "Génie Industriel: Aide à la décision pour les systèmes de production et de distribution". Marie-Claude Portmann is responsible of the Mastère "Management de la chaîne logistique - Achats" ENSMN, ICN, ENSGSI and ESIDEC.

Marie-Claude Portmann is member of the national committee CTI (Commission des Titres d'Ingénieurs), who visits the French Engineer Schools and decides if they can continue to deliver the Engineer Diploma.

Nidhal Rezg is responsible of the DESS Automatisation et Organisation Industrielles (University of Metz) and of the DESS GMP Conception des Systèmes Intégrés de Production (University of Metz).

Didier Anciaux is responsible of the Licence Professionnelle Gestion de la Production Industrielle (University of Metz).

Alexandru Sava is responsible of the Option Quality (ENIM).

Sophie Hennequin is co-responsible of the option Research and development (ENIM).

Thibaud Monteiro is the teaching person in charge of the Licence Professionnelle Gestion de la Production Industrielle (University of Metz).

MACSI belongs to the graduate school IEAM. Many members of MACSI give courses within the Master Conception, Industrialisation et Innovation of Metz (Sophie Hennequin, Marie-Claude Portmann, Nidhal Rezg, Nathalie Sauer, Alexandru Sava and Xiaolan Xie).

9. Bibliography

Doctoral dissertations and Habilitation theses

[1] Z. ACHOUR. *Contribution a la synthèse des controleurs des systèmes à événements discrets partiellement observables*, Thèse de doctorat, ENIM, October 2005.

[2] J. FONDREVELLE. *Résolution exacte de problèmes d'ordonnancement de type flowshop de permutation en présence de contraintes d'écarts temporels entre opérations*, Thèse de doctorat, INPL, November 2005, http://tel.ccsd.cnrs.fr/tel-00011065.

[3] L. OUZIZI. *Planification de la production par co-décision et négociation de l'entreprise virtuelle*, Ph. D. Thesis, Université de Metz, January 2005.

Articles in refereed journals and book chapters

[4] A. ALOULOU, M.-C. PORTMANN. *Une approche proactive réactive efficace : cas d'un atelier d'assemblage*, in "Flexibilité et robustesse en ordonnancement", J.-C. BILLAUT, A. MOUKRIM, E. SANLAVILLE (editors). , IC2, chap. 10, Hermès Lavoisier, 2005, p. 243-261.

[5] M. ALOULOU, M.-C. PORTMANN. *An efficient-proactive reactive approach to hedge against shop floor disturbances*, in "In Special Issue of the 1st Multidisciplinary International Conference on Scheduling : Theory and Applications – MISTA'2003", G. KENDALL, E. BURKE, S. PETROVIC, M. GENDREAU (editors). , Springer, 2005, p. 223-246.

[6] A. CHELBI, N. REZG. *Analysis of a production-inventory system with randomly failing production unit subjected to a minimum required availability level*, in "International Journal of Production Economics", vol. 99, 2005, p. 131-143.

[7] S. DELLAGI, N. REZG, X. XIE. *Preventive Maintenance of Manufacturing Systems Under Environmental Constraints*, in "International Journal of Production Research", To appear, 2005.

[8] H. DING, L. BENYOUCEF, X. XIE. *A Simulation-based multi-objective genetic algorithm Approach for Networked enterprises optimization*, in "Accepted by EAoAI international journal (Engineering Applications of Artificial Intelligence)", 2005.

[9] G. FLEURY, P. LACOMME, C. PRINS, W. RAMDANE-CHERIF. *Improving Robustness of Solutions to Arc Routing Problem*, in "Journal of the Operational Research Society", vol. 56, n° 5, May 2005, p. 526-538.

[10] J. FONDREVELLE, A. ALLAHVERDI, A. OULAMARA. *Permutation flowshops with exact time lags to minimize maximum lateness*, in "International Journal of Agile Manufacturing", To appear, 2005.

[11] A. JANIAK, M. KOVALYOV, M.-C. PORTMANN. *Single machine group scheduling with resource dependent setup and processing times*, in "European Journal of Operational Research", vol. 162, nº 1, April 2005, p. 112-121.

[12] P. LACOMME, C. PRINS, W. RAMDANE-CHERIF. *Evolutionary algorithms for periodic arc routing problems*, in "European Journal of Operational Research", vol. 165, nº 2, September 2005, p. 535-553.

[13] A. OULAMARA, M. KOVALYOV, G. FINKE. *Scheduling a no-wait flowshop with unbounded batching machines*, in "IIE Transactions on Scheduling and Logistics", vol. 37, 2005.

[14] A. OULAMARA. *Makespan minimization in a no-wait flowshop problem with two batching machines*, in "Computers and Operations Research", In press, available on line, July, 2005.

[15] N. REZG, A. CHELBI, X. XIE. *Modeling and optimizing a joint buffer inventory and preventive maintenance strategy for a randomly failing production unit: Analytical and simulation approaches*, in "International Journal of Computer Integrated Manufacturing", vol. 18, 2005, p. 225-235.

[16] D. ROY, D. ANCIAUX, T. MONTEIRO, L. OUZIZI. *Multi-agent architecture for supply chain management*, in "IMS - Special Issue on Logistics and Supply Chain Management with Artificial Intelligent Techniques", to appear, 2005.

Publications in Conferences and Workshops

[17] Z. ACHOUR, N. REZG, X. XIE. *On the existence of Petri net Controller for Discrete Event Systems under Partial Observation*, in "16th IFAC WORLD CONGRESS, Praha, Czech Republic", July 2005, CDROM.

[18] Z. ACHOUR, N. REZG, X. XIE. *Petri net controller synthesis using theory of regions*, in "1st I*PROMS Virtual International Conference on Intelligent Production Machines and Systems", July 2005, CDROM.

[19] H. AMET, J. COHEN, F. DEPPNER, M.-C. PORTMANN, S. ROUSSEAU. *Un problème d'ordonnancement de messages : Partie 1 Modélisations ; Partie 2 Approches de résolution*, in "ROADEF2005, Tours", February 2005, p. 54-57.

[20] D. ANCIAUX, D. ROY, S. MIRDAMADI. *Un Modèle de Chaîne Logistique avec prise en Compte des Moyens de Transports Intermodaux*, in "CPI 2005, 5ième conférence sur la conception et la production intégrée, Casablanca, Morocco", October 2005.

[21] L. BENYOUCEF, N. REZG, X. XIE, H. DING. *Production Planning generation in an assembly system with consideration of social and industrial constraints*, in "Proceedings of the 2nd IEEE International Conference on Service Operations and Logistics, and Informatics, Beijing (China)", August 2005, p. 817-823.

[22] A. CHELBI, N. REZG, M. RADHOUI. *Simultaneous determination of production lot size and preventive maintenance schedule for unreliable production system producing conforming and nonconforming units*, in "International Conference on Industrial Engineering and Systems Management, Marrakech, Maroc", May 2005, CDROM.

[23] S. DELLAGI, N. REZG, A. CHELBI. *Contribution à l élaboration d une politique de commande optimale*

intégrant la maintenance : Cas d une demande aléatoire, in "6ème congrès international de génie industriel, Besancon, France", June 2005, CDROM.

[24] G. FINKE, M. Y. KOVALYOV, A. OULAMARA. *Batch scheduling in a no-wait flowshop*, in "ECCO XVIII, Minsk, Belarus", May 2005, 17.

[25] J. FONDREVELLE, A. OULAMARA, M.-C. PORTMANN. *Approche de résolution pour les problèmes de flow-shop avec time-lags minimaux et maximaux*, in "6ème Congrès de la Société Française de Recherche Opérationnelle et d'Aide à la Décision ROADEF'05, Tours, France", Laboratoire d'Informatique de l'Université de Tours, February 2005.

[26] J. FONDREVELLE, A. OULAMARA, M.-C. PORTMANN. *Minimizing makespan in flowshop with time lags*, in "Models and Algorithms for Planning and Scheduling Problems - MAPSP'2005, Siena, Italy", June 2005.

[27] J. FONDREVELLE, A. OULAMARA, M.-C. PORTMANN. *Minimizing the weighted sum of machine completion times in flowshop with time lags : complexity results and a solution approach*, in "International Conference on Industrial Engineering and Systems Management - IESM'05, Marrakech, Maroc", Actes sur CD-Rom, May 2005.

[28] S. KAMESHWARAN, L. BENYOUCEF. *A Branch-and-Bound Framework for Optimal Winner Determination in Combinatorial Auctions with Interval Bids*, in "Accepted in 1st International Conference on Information Systems, Logistics and Supply Chain, Lyon (France)", May 2005.

[29] S. KAMESHWARAN, L. BENYOUCEF. *Multiunit Discount Auctions*, in "Proceedings of the Fifth ALIO/EURO conference on combinatorial optimization, Paris (France)", October 2005.

[30] S. KAMESHWARAN, L. BENYOUCEF, X. XIE. *Design of Progressive Auctions for Procurement based on Lagrangian Relaxation*, in "Proceedings of the 7th IEEE International Conference on E-Commerce Technology, Munich (Germany)", July 2005, p. 9-16.

[31] S. KAMESHWARAN, L. BENYOUCEF, X. XIE. *Discount Auctions for Procuring Heterogeneous Items*, in "Proceedings of the ICEC05 7th International Conference on Electronic Commerce, Xi'An (China)", August 2005, p. 244-249.

[32] S. KAMESHWARAN, L. BENYOUCEF, X. XIE. *Winner determination in discounts auctions*, in "Proceedings of the 1st International Workshop on Internet and Network Economics, Lecture Notes in Computer Science 3828, Hong Kong (China)", December 2005, p. 868-877.

[33] S. KHOUIDER, T. MONTEIRO, M. PORTMANN. *Outil d'aide à la recherche de nouveaux fournisseurs*, in "Journées d'Optimisation - JOPT 2005, Montréal, Canada", 2005.

[34] S. KHOUIDER, T. MONTEIRO, M.-C. PORTMANN. *Suppliers searching tool in cooperative supply-chain management*, in "47e congrès annuel de la Société canadienne de recherche opérationnelle - CORS 2005, Halifax, Canada", 2005.

[35] J. LI, A. SAVA, X. XIE. *An Analytical Approach for Performance Evaluation and Optimization of a Two-stage Production-distribution System with Batch Orders* , in "16th IFAC World Congress, Prague", July 2005,

CDROM.

[36] T. MONTEIRO, T. DUBA, N. REZG. *La Simulation des Processus Manufacturiers - problématique et démarche pédagogique*, in "Journée GI'2005, Ingénierie pédagogique et approches de simulation, Paris, France", 2005.

[37] Z. MOULOUA, A. OULAMARA, W. RAMDANE-CHERIF. *Approche par décomposition pour le problème de planification de tournées de personnel*, in "6ème congrès de la Société Française de Recherche Opérationnelle et d'Aide à la Décision - ROADEF'2005, Tours, France", February 2005.

[38] I. MOURANI, S. HENNEQUIN, X. XIE. *Continuous Petri nets with delays for performance evaluation of transfer lines*, in "IEEE International Conference on Robotics and Automation (ICRA), Barcelona", April 2005, CDROM.

[39] I. MOURANI, S. HENNEQUIN, X. XIE. *Performance analysis of two-machine continuous-flow model with delay*, in "Intelligent production machines and systems (IPROMS), Cardiff", July 2005.

[40] I. MOURANI, S. HENNEQUIN, X. XIE. *Simulation-based Optimization of a Single-Stage Failure-Prone Manufacturing System with Transportation Delay*, in "International Conference on Industrial Engineering and Systems Management(IESM), Marrakech", May 2005, CDROM.

[41] A. OULAMARA. *Makespan minimization in no-wait flowshop with two batching machines*, in "ECCO XVIII, Minsk, Belarus", May 2005, 49.

[42] L. OUZIZI, M.-C. PORTMANN, F. VERNADAT. *Aide à la decision pour la planification d'une chaîne logistique en utilisant une architecture de pilotage semi-distribuée*, in "GI 2005, Besançon", June 2005.

[43] M. PORTMANN, H. AMET, F. DEPPNER. *Approximation solution approaches for a ring no-wait flow shop scheduling problem*, in "ECCO XVIII, Minsk, Belarus", May 2005, 54.

[44] N. REZG, X. XIE, Z. ACHOUR. *Petri Net Techniques in Supervisory Control of Discrete Event Systems*, in "workshop on Control of Hybrid and Discrete Event Systems a satellite event of the 26th International Conference on the Application and Theory of Petri Nets and other Models of Concurrency, Miami, Florida, USA", June 2005.

[45] G.-A. TANONKOU, L. BENYOUCEF, R. BISDORFF, X. XIE. *Solving a stochastic inventory-location problem using Lagrangian relaxation approach*, in "Proceedings of the 1st IEEE International Conference on Automation Science and Engineering, Edmonton (Canada)", August 2005, p. 279-284.

[46] G.-A. TANONKOU, L. BENYOUCEF, X. XIE. *An efficient Lagrangian heuristic for stochastic facility location problem analysis*, in "Proceedings of the 2nd IEEE International Conference on Service Operations and Logistics, and Informatics, Beijing (China)", August 2005, p. 219-224.

[47] G.-A. TANONKOU, L. BENYOUCEF, X. XIE. *Problème de localisation de centres de distribution dans une chaine logistique avec prise en compte du niveau de service client*, in "Proceedings of the 1st International Conference on Operational Research Practice in Africa, Ouagadougou (Burkina Faso)", April 2005.

[48] G.-A. TANONKOU, L. BENYOUCEF, X. XIE. *Un Problème stochastique de localisation de centres de distribution dans une chaine logistique*, in "Actes du 6ième Congrès International de Génie Industrielle, Besançon (France)", June 2005.

[49] G. THISSELIN, A. OULAMARA, W. RAMDANE-CHERIF, M.-C. PORTMANN. *Methodes d optimisation combinatoire pour un probleme d optimisation de maintenance corrective*, in "ROADEF 2005", February 2005.

Internal Reports

[50] Z. ACHOUR, N. REZG. *Time Floating General Mutual Exclusion Constraints (TFGMEC)*, submitted to IEEE Transactions on Control Systems Technology, Technical report, 2005.

[51] H. DING, L. BENYOUCEF, X. XIE. *Production-distribution Network Design Using Simulation-Based Optimization*, submitted to IEEE-SMC Part C journal, Technical report, 2005.

[52] H. DING, L. BENYOUCEF, X. XIE. *Simulation-based multiobjective optimization for supplier selection: With an application in textile industry*, submitted to European Journal of Operational Research 'Special issue on Evolutionary Multiobjective Optimization', Technical report, 2005.

[53] J. FONDREVELLE, A. OULAMARA, M.-C. PORTMANN. *Permutation flowshops with time lags to minimize the weighted sum of machine completion times*, submitted to International Journal of Production Economics, Technical report, 2005.

[54] M. HAJ-RACHID. *Optimisation de la production et des tournées de livraison*, Rapport DEA Génie des Systèmes Industriels, INPL, 2005.

[55] S. KAMESHWARAN, L. BENYOUCEF, X. XIE. *Discount Auctions for Multi-Item Procurement*, submitted to European Journal of Operational Research, Technical report, 2005.

[56] A. K. KUTTEING. *Flowshop avec machine à traitement par batch et compatibilité entre les tâches*, Rapport Master Recherche, Paris 6, 2005.

[57] A. MENG, L. YE, D. ROY, P. PADILLA. *Genetic Algorithm Based Multi-Agent System Applied to the Automatic Generation of Exam Papers*, submitted to JCAL, 2005.

[58] T. MONTEIRO, D. ROY, D. ANCIAUX. *Multi site coordination using multi-agent system*, submitted to Computers in Industry, Technical report, 2005.

[59] I. MOURANI, S. HENNEQUIN, X. XIE. *Failure models and throughput rate of transfer lines*, submitted to IJPR, 2005.

[60] M.-C. PORTMANN, A. OULAMARA. *Optimisation discrète*, Revue des techniques de l'ingénieur, 2005.

[61] G.-A. TANONKOU, L. BENYOUCEF, X. XIE. *A stochastic distribution network design with constant supply lead-times*, submitted to Journal of the Operational Research Society (August 2005), Technical report, 2005.

Bibliography in notes

[62] B. ARNTZEN, G. BROWN, T. HARRISON, L. TRAFTON. *Global supply chain management at Digital Equipment Corporation*, in "Interface", vol. 25, 1995, p. 69–93.

[63] F. AZADIVAR. *Simulation optimization methodologies*, in "Proc. 1999 Winter Simulation Conference", 1999, p. 93–100.

[64] G. CACHON, M. LARIVIERE. *Contracting to assure supply: how to share demand forecasts in a supply chain*, in "Management Science", vol. 47, nº 5, 2001, p. 629–647.

[65] M. CHRISTOPHER. *Logistics and supply chain management: strategies for reducing costs and improving services*, in "Financial Times", 1992.

[66] M. DAHANE, T. MONTEIRO. *Distributed Information System for Cooperative Supply-Chain Management*, in "MCPL2004, Santiago, Chile", 2004.

[67] W. DAVIDOW, M. MALONE. *L'entreprise à l'âge du virtuel*, in "MAXIMA", Paris, Institut du management d'EDF et de GDF, 1995.

[68] GOTHA. *Les problèmes d'ordonnancement*, in "Recherche Opérationnelle/Operations Research", vol. 27, nº 1, 1993, p. 77–150.

[69] S. GAVIRNENI, S. KAPUSCINSKI, S. TAYUR. *Value of information in capacitated supply chains*, in "Management Science", vol. 45, nº 11, 1999, p. 16–24.

[70] A. GHAFFARI, N. REZG, X. XIE. *Design of Live and Maximally Permissive Petri Net Controller Using Theory of Regions*, in "IEEE Trans. on Robotics and Automation", vol. 19, nº 1, 2003, p. 137–142.

[71] V. GIARD. *Gestion de la production et des flux*, 3ème édition, Economica, Paris, France, 2003.

[72] M. HARDWICK, R. BOLTON. *The industrian virtual entreprise*, in "Communications of the ACM", vol. 40, nº 9, 1997.

[73] L. J. HONG, B. NELSON. *Discrete Optimisation via Simulation using COMPASS*, in "Operations Research", 2004.

[74] D. KJENSTAD. *Coordinated supply chain scheduling*, Ph. D. Thesis, Departement of production and quality engineering, Norwegian University of Science and Technology, 1998.

[75] B. H. KROGH. *Controlled Petri nets and maximally permissive feedback logic*, in "25th Annual Allerton Conference, Urbana, IL", 1987, p. 317–326.

[76] H. LEE, C. BILLINGTON. *Material management in decentralized supply chain*, in "Operations research", vol. 41, 1993, p. 835–847.

[77] T. W. MALONE, K. CROWSTON. *The interdisciplimary study of coordination*, in "ACM Computing Survey", vol. 26, nº 1, 1994.

[78] T. MONTEIRO, P. LADET. *Formalisation de la coopération dans le pilotage distribuée de flux interentreprises : application á une entreprise de production de biens*, in "JESA", Numéro spécial - Pilotage distribué, vol. 7–8, 2001, p. 963–989.

[79] P. RAMADGE, W. WONHAM. *Supervisory control of a class of discrete event processes*, in "SIAM J.Control Optimiz.", vol. 25, nº 3, 1987, p. 206–230.

[80] K. ROTA. *Coordination temporelle de centres gérant de façon autonome des ressources – application aux chaines logistiques intégrées en aéronautique*, Ph. D. Thesis, Université Paul Sabatier, 1998.

[81] F. ROUBELLAT, P. LOPEZ. *Ordonnancement de la production*, Hermès, Paris, France, 2001.

[82] D. ROY, D. ANCIAUX, T. MONTEIRO, L. OUZIZI. *Multi-agent architecture for supply chain management*, in "Journal of Manufacturing Technology Management (ex IMS) - Special Issue on Logistics and Supply Chain Management with Artificial Intelligent Techniques", vol. 15, nº 8, 2004, p. 745–755.

[83] G. SALVENDY. *Handbook of industrial engineering*, John Wiley, New York, U.S.A., 1992.