INRIA

INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Team costeam

Optimal and secure management of manufacturing systems

Nancy - Grand Est

Theme : Modeling, Optimization, and Control of Dynamic Systems

Table of contents

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2. Overall Objectives

2.1. Overall Objectives

The COSTEAM project deals with optimal and secure management of discrete systems producing goods and services. Its main objectives are systems design, analysis and control.

Systems producing goods or services play a fundamental role in our economical environment which is facing major changes. In industrial production, the buzzword is no more productivity but capacity to react or agility. The preservation or the improvement of the competitiveness of an industrial or service system is strongly influenced by its environment, i.e. by the evolution of the market, by production technologies and by the people involved in its operations. Concerning the tomorrow's market, the economic studies are unanimous. The market evolves towards high-quality, low-cost products, of large variety (some even talk about personalized products or mass customization) and renewed more frequently. It constantly evolves and becomes more and more difficult to predict. In such a very strongly competitive context, the performance of companies depends on their flexibility and their ability to react. The technological answer to this challenge relies on flexible and reconfigurable systems. A flexible manufacturing system has a high level of automation and uses sophisticated resources such as digitally operated machines, robots, etc. The amount of investments due to flexible systems requires a detailed preliminary study. Such a study requires a design phase comprising stages for modeling, analysis, performance evaluation and control synthesis of the future systems, even before these are settled. Their reconfiguration uses the same techniques to improve or adapt constantly these systems to the needs of the market. Due to the globalization of economies, companies must be competitive in terms of costs, delays and quality. They must be flexible to meet the fluctuating demands and they must be reactive to face the exogenous and endogenous changes they undergo. More than ever they need rational tools and structured methods to better control the flows of products, information and decision, and to archive a better reliability of the production resources. The control of the whole supply chain, going from the suppliers to the consumers and encompassing all the stages of production, becomes a necessity. The objective of the COSTEAM project is to develop tools and methods which can help companies to design, model, evaluate and manage their production systems. Accurately, starting from industrial needs, we develop methods for modeling and evaluating performances, as well as associated tools and methodologies to help manufacturers to better design and manage their production systems of goods and services.

3. Scientific Foundations

3.1. Themes

Project COSTEAM addresses three complementary themes:

Theme 1: Performance evaluation and systems sizing

The aim of this theme is to evaluate systems producing goods and services in order to design/re-design them or to provide them with efficient management and development strategies. Both generic optimization methods dedicated to common systems and analytical and simulation methods dedicated to more particular systems are addressed in this theme.

Theme 2: Optimal control of systems

This theme deals with designing of controllers for discrete event systems. The control synthesis of discrete event systems including time constraints and the uncontrollable/unobservable nature of some events is addressed. We pay special attention to the notions of deadlock avoidance and recoverable systems for the case of industrial systems. The aim is to build the less restrictive control law which guarantees that the behavior of the system respects given specifications.

Theme 3: Reliability and maintenance systems

This theme deals with the development of efficient maintenance policies in the context of the production of goods or services under strong constraints. The proposed policies are developed by taking into account the production plan and the maintenance plan of the manufacturing system. The main challenge of these topics is the integration of modeling and optimization techniques within a unified analysis process to design and to manage a complex system and then to synthesize its control. We give special attention to modeling

of the machines dégradation, to modeling of the maintenance activities and to related data and information intégration and analysis, starting from the design phase of the manufacturing system.

The themes presented above intend to develop systems producing goods and services, and more generally enterprise networks, with optimized strategies of control. For our case studies, we do not consider isolated entities, but we take into account the relationships existing between the various partners. Two domains of application are considered:

- textbfIndustrial systems and services systems (such as hospitals). We consider an entity that produces goods or services, taking into account complex constraints as well as interactions with its customers and its suppliers. We develop both analytical methods and generic methods to optimize the behavior of such systems.
- textbfEnterprise networks. On the basis of models developed in the MACSI project, for this kind of application we study the operational management of the whole supply chain with respect to the organization, the monitoring and the optimization of this supply chain. We also consider e-procurement business subject to a certain amount of constraints within the framework of open markets via new technologies of information and communication.

3.2. Scientific Foundation

The performance evaluation and systems sizing aspect is very important for both application domains. Indeed, the research in this field is connected to the developments of discrete event systems. It is often caricatured by the rivalry between analytical methods and simulation. Some recent results allow to get rid of this rivalry and to make analytical methods and simulation complementary. Thus we develop analytical methods on the basis of simulation to evaluate and optimize systems producing goods and services. A new dimension in this research is the simultaneous consideration of the imperatives of production and the maintenance policies as well as the implementation of relevant indicators. Other research topics such as the study of hybrid systems (Discrete Event Systems and Continuous Systems) could be mentioned. In order to avoid dispersion of our research energy, these systems will not be approached on a short term but may be studied if the opportunity appears (i.e. industrial contracts) and if the human resource potential of the project allows.

COSTEAM project falls under the INRIA topic entitled "Numerical systems - Control and complex systems". It aims at proposing solutions and participating in knowledge advancement related to design, evaluation and management of discrete systems producing goods or services. The research goal is resolutely dual, giving top priority to fundamental research on one hand but always keeping in mind industrial applications on the other hand. On the short-term, we will thus focus on well-identified problems of design, performance evaluation, systems optimization, maintenance policies definition, and also optimization of e-sourcing. Thanks to this experience, the aim on the long-term (5 years and more) is to develop a systematic method to design and analyze systems producing goods or services based on modeling and formal specifications of the structure and control of these systems, like software engineering does. The COSTEAM project takes benefits from the activities of the "Systémes de production (SdP)" team of the "Laboratoire de Génie Industriel et Production Mécanique" (LGIPM), common to ENIM, ENSAM-Metz and University Paul Verlaine of Metz. Most of its members belonged to the former MACSI project of INRIA.

The COSTEAM project is built on concrete industrial needs which concern problems of design, management and optimization of systems producing goods or services. Our research activity relies on conventional tools like operational research, Petri nets, perturbation analysis and others for solving problems encountered in designing and managing systems producing goods and services. These tools are the foundation for developing new methodologies more adapted to the industrial applications and the research challenges we are facing.

4. Application Domains

4.1. Application Domains

For a long time, only systems producing goods were studied with a lot of applications in the manufacturing world. More recently, systems producing services have been considered. These kinds of systems include government services, banks, health services and hospitals, maintenance services, large distribution channels, etc. A common feature to these fields is their strong socio-technical component, the role of human beings remaining the driving force of these systems, throughout many functions (actor, decision-maker, operator, customer, etc). Thus it is very important to consider also these systems, by integrating new constraints (and more particularly the social, economical, technological and environmental ones), together with the complexity of the proposed systems with their human dimension. Therefore, the COSTEAM project tackles the study of critical problems of optimization and decision-making existing in logistic systems, production systems and services systems. The goal is to evaluate, design and manage the following kind of systems:

Manufacturing systems such as:

- Discrete systems, existing for instance in the automotive industry, aeronautics or mechanical production;
- High-speed systems (with high rate flow of parts) or current flow systems that are very common in companies from various industrial sectors (e.g. food industry, pharmaceutics, cosmetics, electronics).

Services systems (government services, banks, health services, maintenance services, etc). The problems encountered are diversified. For instance, they can concern the definition of timetables; the determination of maintenance plans by maintenance agents.

Logistic systems (supplying, production, distribution and transport), under their strategic, tactical and operational aspects. More specially, we are interested in:

- The logistical and industrial strategy and the problems related to location and sizing of logistic and industrial units;
- The scheduling and optimization of supplies, stocks and distribution;
- The scheduling and optimization of load transport, and more particularly long-distance transport, combined transport and vehicles rounds, supplying transport, inter-factories transport and distribution.

Among all these domains, a new application field addressed in our team is the e-sourcing, which is a network of electronic management purchasing. Indeed, the emergence of new technologies provides manufacturing companies with new solutions to increase their competitiveness. E-sourcing represents an effort from companies in their use of Internet to optimize their purchases using electronic trade, on-line services for calls for proposals, virtual market places, etc.

The Internet and the Web services allow companies to get over the geographical limits, to take benefits of a worldwide market and to build new relationships between customers and suppliers. A well-managed project based on e-sourcing is a major source of profits and reduction of administrative expenses.

However these technologies also bring new risks and weaken companies exploiting the worldwide market. This is the reason why one of the key factors for success is the capacity of companies to integrate an unstable relational framework, oscillating according to the object and the moment.

Studying the customers-suppliers relationships in the context of the e-sourcing, integrating the e-sourcing into the optimization of a purchasing program taking into account risk factors (economical, social and environmental ones) are the main objectives of our research in this application field.

5. New Results

5.1. Performance evaluation and systems sizing

Participants: Lyes Benyoucef, Sophie Hennequin, Nidhal Rezg, Nathalie Sauer, Alexandre Sava.

This part concerns the performance evaluation of critical problems. Setting up a new production system of goods or services, or modifying either the physical structure or the operation of an existing system, requires the system's performance to be evaluated and optimized.

5.1.1. Industrial systems and services systems

The first general subject concerns the scheduling of flexible systems (production or services) without storage capacity and with a specific blocking constraint encountered in many industrial processes. In classical blocking situations, a machine remains blocked by a job until this job starts the operation on the next machine in the routing. For the particular type of blocking constraints considered in our work, the machine remains blocked by a job until its operation on the downstream machine is finished (RCb constraint). Another new type of blocking constraint has been proposed and defined [48]. Heuristics and genetic algorithms for solving these Flow-shop problems are developed and different initial populations are tested to find the best adapted [19], [39]. To solve the Job-Shop scheduling problem, possible conflicts situations are characterized and a heuristic method which avoids conflicting situations has been proposed [48]. In [35], a necessary and sufficient condition to obtain this conflict is presented, a lower bound to solve this problem is given and a meta-heuristic method based on simulated annealing is presented to obtain a solution. Its performances are compared with the optimal solutions until certain size and lower bound for more complex problems.

The impact of delays such as transportation, production or lead-times, is also studied in another aspect of our research program. The basic idea of this study is to develop Perturbation Analysis (PA) for performance evaluation and optimization of failure-prone manufacturing systems. Indeed, in the domain of discrete event systems, it was discovered in the early 1980s that event-driven dynamics give rise to state trajectories (sample paths) from which one can very efficiently and nonintrusively extract sensitivities of various performance metrics with respect to at least certain types of design or control parameters. This has led to the development of a theory for perturbation analysis in discrete event systems. Using PA, one obtains unbiased gradient estimates of performance metrics that can be incorporated into standard gradient-based algorithms for performance evaluation and optimization purposes. Systems with delays hardly have begun to be investigated, and the few existing results indicate that the problem may become challenging, and the PA derivatives are more complicated than those that would be obtained for the system without delay. In our work we consider two models: discrete and continuous flow models, with inclusion of delivery times for more realistic performance evaluation and optimization of failure-prone manufacturing systems. While in most traditional continuous flow models the flow rates involved are treated as fixed parameters, a continuous flow model has the extra feature of treating flow rates as stochastic processes. Furthermore, continuous models have been shown to be very useful in simulating various kinds of high volume manufacturing systems and in this case are a good approximation of discrete settings. However, when the study should consider each part independently, discrete flow models are more appropriate. Unfortunately, PA estimates could become in this case biased (hence unreliable for control purposes) when significant discontinuities in sample functions appear. One salient feature of our work is the explicit modeling of delays without destroying the nature of pure continuous and discrete flow models. Thus, the main innovation of our research is to consider these both models with delays and to define PA estimates for performance evaluation and optimization. In a first step, discrete flow model for a simple manufacturing system composed by a failure-prone machine, a buffer and a customer is considered. The demand is stochastic and the delivery time between the buffer and the customer is supposed to be constant. The control policy applied to the machine is a hedging point policy which has been proved to be optimal for a system without delivery times and which ensures that the material does not exceed a given number of parts. A simulation based on perturbation analysis is then proposed for performance evaluation and optimization. The goal of the optimization is to evaluate the optimal buffer level (hedging point) to minimize the total cost function which is the sum of inventory cost, backlog cost, transportation cost [66]. The PA estimates are shown to be unbiased and comparison with discrete event system simulation proves that our results are very interesting and performing. In a second step of our work, the study of both continuous and discrete flow models with constant delivery times is pursued. By theoretical and numerical results it is shown that these models have the same behavior and for each model unbiased gradient estimates are obtained [50] .

Reconfigurable manufacturing systems (RMS) have been acknowledged as a promising means of providing manufacturing companies with the required production capacities and capabilities. This is accomplished through reconfiguring the system elements over the time for a diverse set of individualized products often required in small quantities and with short delivery lead time. In [7], we propose a new approach to generate the dynamic process plan for reconfigurable manufacturing system. Initially, the requirements of the parts/products are assessed which are then compared with the functionality offered by machines comprising manufacturing system. If the production is feasible an optimal process plan is generated, otherwise the system shows an error message showing lack of functionality. Using an adapted NSGA-2 algorithm, a multi-objective scenario is considered with the aim of reducing the manufacturing cost and time. Moreover, to map the manufacturing system capabilities and other characteristics, RMS necessitate the developpment of a suitable index. As a new result, we developed an index to measure the reconfigurability of RMSs keeping in mind their various core characteristics such as modularity, scalability, convertibility and diagnosability. These characteristics are mapped together using Multi-Attribute Utility Theory (MAUT). We can easily use this index to find the reconfigurability of a system possessing different characteristics [11].

5.1.2. Case of supply chains

This subject concerns supply chains. We begin by the more classic logistic systems, and then move on to enterprise networks which are characterized by an extensive use of information technology.

In the recent years, internet technologies have yielded a range of applications and decision support tools to manage the procurement process between industrial buyers and their suppliers. These tools aid in contract negotiation, cost analysis, supplier selection and optimal supplier performance. They provide the firms opportunities for entering new market, lowering their transaction cost, and improving their supply chain management capabilities while improvising their profitability over coming years. This process of identifying, evaluating and configuring the optimal grouping of buyers and suppliers in a supply chain using internet is often referred as e-sourcing. Traditionally e-sourcing are based on reverse auction or electronic auction which is an online, real-time dynamic auction between a industrial buyer and a group of its pre-qualified suppliers who compete against each other to win the business to supply goods or services that have clearly defined specifications for design, quantity, quality, delivery, and related terms and conditions. As results, we formulated the winner determination problem of multi-criteria reveres auction as multi criteria decision making problem and an extension of TOPSIS method based on fuzzy logic and interval arithmetic is proposed to solve the decision problem. In some cases, precise values are inadequate to model the criteria in real life. Therefore, we used fuzzy linguistic variables to map qualitative criteria in order to remove the vagueness of the decision makers and at the same time interval data is used for quantitative preferences which are difficult to be represented by exact numerical values. Correlation coefficient and standard deviation integrated (CCSD) methodology is proposed for automatic enumeration of the criteria weights and a mechanism is also developed for determination of the preferences of qualitative criteria using fuzzy linguistic variables [21], [22].

Supplier selection with order splitting represents one of the most important functions to be performed by the purchasing department that determines the long-term viability of dynamic supply chains. As a second result, a novel approach for automatic knowledge acquisition, which clubs supplier selection process with order splitting for dynamic supply chains based on the attained knowledge from the variations in the market is developed. Moreover, the suggested approach imitates the knowledge acquisition and manipulation in a manner similar to the human schedulers who have gathered considerable knowledge and expertise in a given domain. As per this concept, those decision criteria for supplier selection are considered first, which are qualitatively meaningful like performance, service quality, innovation, risk etc. and thereafter their application is quantitatively evaluated. State variables are derived from the decision criteria to match the factors (flexibility, responsiveness, agility, position etc) associated with local competitive situation of the candidate supplier. Therefore, logically it can be inferred that the developed approach can generate decision making knowledge as a result, the developed combination of rules for supplier selection can easily be interpreted, adopted and at the same time if necessary, modified by supply chain decision makers [55], [54].

Moreover, another research direction addresses the development of an intelligent simulator for complex supply chains analysis. It is well know that most of the simulation tools are able to map large size supply chains and

can accommodate complex random phenomena. Nevertheless, they have significant weakness in the power of decision-making. Indeed, most of the problems of decision-making are typically determined by simplified rules. For this reason, involving optimization tools in decision-making will allow the simulation to explore the real performance of a supply chain. Motivated by the limitations of existing supply chains simulation and optimization tools, as a result we combined them in a single tool. More specifically, we developed an 'intelligent' simulation tool with an embedded optimization tool to solve various decision-making problems encountered during the simulation of a complex supply chain. Including an optimization tool in a simulation tool allows accurate assessment of supply chains performances and overcome the lack of powers of decision-making in traditional simulation tools [5], [33].

Another research area for our team concerns the traceability phenomenon implementation within the production organization, particularly in the field of raw materials management in the food industry. The objective is to minimize the raw material's dispersion in the manufactured products. We seek to solve the problem of raw materials allocation into finished products, in order to minimize its dispersion and moreover, the products recall if needed. Dispersion optimization has been obtained using a genetic algorithm. The dispersion criteria are afterwards used to determine production's criticality in terms of sanitary risk, from which it is possible to optimize the processes of picking and dispatching. In [47], we explore an approach to the risk measurement problem of any multi-parameter production framework using precise decision making tools. The application model of artificial neural networks is presented in order to determine the global risk related to a given production. The proposed tool uses a feed-forward network able to treat any set of nonlinearly separable production markers. The risk values obtained with this approach are incorporated into the expedition management system in order to perform smarter deliveries and more accurate sanitary controls.

5.2. Optimal control of systems

Participants: Nidhal Rezg, Alexandre Sava.

The research activity that our team develops on this topic concerns discrete event systems modeled by Petri nets. In the past, our team has developed control synthesis techniques based on the theory of regions. These techniques provide efficient controllers to enforce General Mutual Exclusion Constraints on discrete event systems modeled by bounded Petri nets. Furthermore, a particular class of Petri nets, called marked graphs, triggered our attention due to its ability for modeling and performance evaluation of flexible manufacturing system. We proposed an efficient control synthesis algorithm for marked graphs not necessarily bounded. This approach does not take into account the liveness of the closed loop system. However, deadlock avoiding is an important specification for industrial applications. Therefore, we explored this problem while including progressively real specifications like the uncontrollable and/or unobservable nature of some events and the time information on event occurrence.

Thus, we developed a control synthesis approach for partially controllable marked graphs subject to General Mutual Exclusion Constraints. We prove that the risk of deadlock is a consequence of the existence of a particular structure that we call risky transitions. Then, we proposed a sufficient condition to avoid deadlocks and developed a deadlock free control synthesis method for marked graphs not necessarily bounded [46]. This approach was extended in [64] by taking into account the unobservable nature of some events.

Some control synthesis problems are subject to specifications which consist in avoiding given values for the marking of Petri net places. In order to handle these problems, we propose a new type of specifications called Marking Exclusion Constraints (MEC). The main advantage of MEC specification is an increased modeling power regarding General Mutual Exclusion Constraints (GMEC). We define three types of MEC: MEC-OR and MEC-AND and M-MEC and we proposed a technique to build the controller to enforce MEC specifications for discrete events systems modeled by partially controllable marked graphs [29], [28]. The control synthesis problem for partial observable marked graphs subject to marking Exclusion Constraints has been studied in [27].

The principle of control synthesis is to authorize or forbid the occurrence of controllable events according to the state of the system in order to prevent the evolution of the system to states that are not desirable. Time information on the occurrence of the events can be used to compute more permissive control laws as the controller does no longer need to completely forbid the execution of an event. Time introduces a new dimension of considerable interest in DES control, but also of significant complexity. Actually our research work deals deadlock free control synthesis for timed marked graphs subject to GMEC and MEC specifications. Some preliminary work has been done on control synthesis for partially controllable timed marked graphs subject to MEC constraints [59]. However, the deadlock avoidance problem is to be solved.

Another research direction deals with building optimal control laws which aim to optimize given performance criteria while respecting specifications on resource availability and security. The applications concerned by this research activity are the air traffic control systems. The approach we are working on combines time Petri nets and Binary Decision Diagrams to obtain a reasonable size representation for the space state of an air traffic network. A cost function is associated to each state. This cost function takes into account the waiting time before take off, the cost of flight canceling and the cost of carburant burned by the airplane during a flight. This cost function allows the evaluation of given flight plans. Our aim is to build a decision making tool to help air traffic controllers to find the best flight plan while being faced to variations of the capacity of the airways due to weather perturbations. To overcome these perturbations, different flying scenarios are generated which include: 1) delay the flight; 2) using other airways and 3) cancel the flight. The approach that we developed during this year consists in the following steps: 1) build the time Petri net model for the air traffic network; 2) generate the BDD model for the solutions space; 3) associate a cost value to each BDD node and 4) calculate the optimal flight plan based on a Branch and bound approach [62] [60].

Furthermore, we focus on using ordinal optimization techniques to generate good enough flight plans in a reasonable time. We are also concerned with extending this problem to air traffic management systems with multiple airports and dynamic allocation of resources.

5.3. Reliability and maintenance of systems

Participants: Kondo H. Adjallah, Akim Khatab, Sophie Hennequin, Nidhal Rezg.

System reliability and maintenance is an research topic that aims at investigating advanced methods of machines degradation modelling and health condition assessment, and maintenance actions planning, scheduling and decision support while considering the exploitation constraints. Specific issues concern:

- the minimization of unavailability cost of the manufacturing systems, due to failures, subcontracting utilizations, random demands, or breaks of machine's feeding,
- the integration optimization of maintenance policies of manufacturing systems, with development of new methods for improving the performance of systems compared to existing traditional policies,
- the modelling of machines' degradations in relation to its operating conditions, environment and human factors,
- the systems level health condition assessment, based on data and information integration,

Addressing those issues would help industrial companies to enhancing their competitiveness with low-cost productions, a best quality, a higher reactivity to random and customized demands, a quick adaptability to the market changes, etc.

Nowadays, the hard competition between the enterprises brings us to revise the currently adopted strategies of production and maintenance. In fact, the satisfaction of the client in time became a difficult spot since demands are random. In this context, subcontracting is defined as the procurement of products or services from external sources. It is justified by many reasons like cost reduction, production flexibility improvement, skill/resource shortage or proximity to markets. In this context our works deal with problems of management of subcontracting services for subcontractor enterprises. We study the constraint of subcontracting under a combined approach of maintenance management and production control for production system under a supplier - customer relationship with a "principal costumer". In order to increase the exploitation of the

production capacity this system provides subcontracting services to another customer called "contractor", under a subcontractor - contractor relationship. In [8], we considered the profitability of subcontracting activities for subcontractor companies. The subcontracting imposes periods of unavailability of the production unit in order to periodically perform subcontracting tasks. We analytically show the conditions under which subcontracting is profitable, based on a given policies of maintenance, production control and assignment to subcontracting. We discuss profitability of two cases of subcontracting constraints: occasional and long-term relationship. In the first case we integrate the subcontracting task in the subcontractor plan without changing the decision variables values (maintenance interval and stock level). The second case imposes a new optimization of decision variables. For this case, we investigated the problem of the unforeseen extension of the subcontracting duration and its impact on the generated costs of maintenance, inventory and shortage. In the same context, we study analytically the importance of the beginning instant of subcontracting tasks. This study proves that the optimal instant to allocate machine to subcontracting is exactly the moment when the capacity of the stock is reached.

Dealing with the development of new integrated maintenance policies under the subcontracting constraint, another subcontractor aspect is studied. We started by considering two subcontractors which have different service cost and availability rate. The strategy consists at relaying on one of the two subcontractors and switching to the other at certain dates. This strategy is justified and optimized analytically in order to determine the optimal preventive maintenance date for the manufacturing system and the optimal switching dates between the two subcontractors [10]. Furthermore, we proposed a prospect related to this study. The goal is the development of an optimal switching strategy between several subcontractors. We considered the building of a safety stock contrarily to the just in time strategy.

Considering only one subcontractor which satisfies a part of the demand in order to take the possibility of building a safety stock, a new research direction is explored. The objective is to manage simultaneously the integrated maintenance-production plan by determining the optimal safety stock level and the optimal preventive maintenance dates while minimizing the average total costs (production, maintenance, inventory and demand loss) [31].

More then, it's easy to see that the manufacturing system degradation evolve according to the production rate, Thus, for a given randomly demand, we established an optimal production plan which minimizes the average total holding and production costs. Using this optimal production plan and its influence on the manufacturing system failure rate, an optimal maintenance scheduling which minimizes the average maintenance cost has been established. We have solved analytically the problem using the linear quadratic Gaussian (LQG) control theory [13].

Another study deals with the combination between production and maintenance plan for a manufacturing system satisfying a random demand subjected to random failures of the manufacturing system. The aim of this study is to establish an economical production/maintenance plan minimizing the average total cost and to illustrate the significant influence of the production rate on the manufacturing system degradation. Moreover, [30] considered an extended version of the problem by taking into account the demand rejection [30]. Two studies investigating new intelligent integrated maintenance and production or service strategies, dealing with complex reliability problems are presented in [58].

In the same context of the dependence between production and failure rates, we considered the problem of production control when production rates depend on the failure rate. The objective is to determine the production planning over a finite horizon minimizing the generated costs (inventory, production and maintenance).

Another research work uses the prognosis concept to develop a set of maintenance policies which integrate the schedule of maintenance missions performed by navy ship. The prognosis result is based on the evaluation of the degradation law, i.e. by taking into account the variations of the environmental and operational conditions. The aim is to determine the optimal business plan (choice and scheduling missions) combined to an optimal maintenance plan. To model the failure law, we established a relationship between the times between failure (from feedback) and risk factors of each navy mission. Also, we have developed two preventive maintenance policies based on a dynamic failure law for a finite planning horizon. The first preventive maintenance policy is

sporadic *the aim is to determine the number of maintenance activities to perform and the choice of the mission that must be followed by preventive activity, in order to minimize maintenance costs*. The optimal solutions are obtained by the extended great deluge algorithm. The second preventive maintenance policy is periodic. With a numerical procedure, we established the optimal number of maintenance actions [20]. In a recent research work, based on a finite time horizon, we have extended this work by considering a production system, which must satisfy a set of requests. The objective is to determine the best production plan to minimize both the holding costs and maintenance costs [40].

Another research program focuses on the development of models considering the impact of the human factor in the maintenance actions. Indeed, most preventive maintenance models assume that the system is restored to as good as new at each maintenance actions and consider the intervention time as negligible. Hence, the system may not be restored to as good as new immediately after the completion of maintenance action. Our approach is based on a fuzzy logic model which allows taking into account imperfections. These later are essentially due to technician's experience, the level of complexity of the restoration, and the time taken by maintenance actions. After a maintenance, the machine returns to an age between as good as new and as bad as old. Fuzzy logic is preferred over crisp logic because it is relatively easy to implement in this situation considering that the human factor is hardly interpreted by analytical methods because of its unpredictable nature. Simulation-based optimization is used to have a more reactive and accurate tool for parishioners. By taken into account the impact of the imperfections due to human factors, the period for the preventive maintenance, which minimizes the expected cost rate per unit of time or maximizes the availability of the system, is evaluated by a simulation-based optimization. This result has obtain the Highly Commended Award Winner at the Literati Network Awards for Ecellence 2010. The infinitesimal perturbation analysis is also applied to an integrated maintenance problem. The objective is to find conjointly the optimal preventive maintenance period and the optimal buffer level of a simple manufacturing system in order to minimize the total cost including inventory, backlog and maintenance costs. The IPA estimates are shown to be unbiased and these estimates are used in a simulation based optimization to evaluate the optimal buffer level and the optimal preventive maintenance period [61].

Maintenance decision support requires data and information integration and analysis, for the production systems' health conditions assessment and components degradation modelling, in terms of reliability model, diagnosis and prognosis tasks scheduling and optimization are investigated. For example, we developed a new non-parametric statistical method to model the degradation process of components of a system. The system level data and information integration aims at equipments' maintainability and reliability data quality enhancement, health monitoring, failure risks evaluation, maintenance actions decidability studies and lifecycle management. These investigations were recently initiated to address e-maintenance problems arising from the implementation of advanced information and communication technologies for the maintenance decision support. A particular attention is also granted to the study of the relationships between the risks and the security of the system, on the basis of data and information integration.

5.4. National and International Activities

5.4.1. National

- **GIS-3SGS - ICD - LAMIH**

  Kondo H. Adjallah, Lyes Benyoucef and Abdelhakim Khatab are involved in collaborative project ReSyST (Anticipation and Resiliency of SocioTechnical complexes Systems in a global safety approach), with teams of the ICD (Troyes) and of the LAMIH (Valenciennes). It aims at working out a clear statement of the optimization problem of the resiliency function of the sociotechnical systems, based on the risks and resiliency study in relation with threats anticipation.

- **ADENTS**

  COSTEAM and the enterprise ADENTS collaborates in the scope of the traceability management. Simòn Tamayo, PhD student, works with a "contrat CIFRE" in this context.

- **LAGIS (Laboratoire d'Automatique, Génie Informatique et Signal) - École Centrale de Lille**

  Our team collaborate with Professor Étienne Craye, Manager of the SED (Systèmes à Événements Discrets) team of LAGIS, on the subject of controller synthesis for an application in the domain of reconfiguration.
- **LAI (Laboratoire d'Automatique Industrielle) - INSA Lyon (National Institute for Applied Sciences)**

  Nidhal Rezg works in collaboration with Professor Eric Niel (manager of the team "Dependability and Monitoring of Industrial systems" of LAI) on the subject of control tolerating failures.
- **SLP (Systèmes Logistiques et de Production) - IRCCyN**

  (Institut de Recherche en Communication et Cybernétique de Nantes)

  Nathalie Sauer works in collaboration with the SLP team of IRCCyN, especially for which concerns management and development of production systems. She has also been ending the supervision of a PhD student of this lab whose thesis is related to evaluation and optimization of event graphs.
- **CRAN and ICD**

  Kondo H. Adjallah works in collaboration with the CRAN team of Prof. Ragot, the ICD research team of Dr Snoussi and Birragah on data collection management on large structure based on wireless sensors network for maintenance decision support. This collaboration was in the framework of the COSMOS project (design and monitoring of reliable and multiple operation modes systems).

5.4.2. International

- **EAFIT - Medellin-Colombia** Kondo Adjallah and Sophie Hennequin collaborate with Prof. Gabriel Diaz from EAFIT-Colombia. This collaboration consists at developing research studies for multi-carburant engines [24][65] and [63].
- **ESSTT (École Supérieure des Sciences et Techniques) - Tunis-Tunisia**

  Nidhal Rezg collaborates with Prof. Anis Chelbi from ESSTT-Tunisia. This collaboration consists at undertaking research studies in order to develop new industrial integrated maintenance/production strategies with the aim of improving the traditional strategies.
- **ETSMTL (École de Technologie Supérieure) - Montreal-Canada**

  Nidhal Rezg collaborates with Professor Ali Gharbi in the maintenance field.
- **Indian Institute of Technology-Delhi-India**

  Since January 2007, Lyes Benyoucef is collaborating with Professor S. G. Deshmukh and Dr. Vipul Jain from the Department of Mechanical Engineering (IIT-Delhi) on the development of new approaches to address the issue of agility and lean in dynamic integrated supply chains.
- **Indian Institute of Technology-Kharagpur-India**

  Since January 2008, Lyes Benyoucef is collaborating with Professor M.K. Tiwari from the Department of Industrial Engineering and Management (IIT-Kharagpur) on the development of new approaches to address the management of reconfigurable manufacturing systems.
- **IBM-India**

  Since May 2006, Lyes Benyoucef is collaborating with Dr. Kameshwaran Sampath from IBM-India on the development of new techniques to solve some complex optimization problems present in e-sourcing environment.
- **RM (Reliability and Maintenance Network) - Canada**

  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 COSTEAM, exchange their industrial and scientific experiences and results on reliability and maintenance of production systems.

- **Technological Institute of Celaya - Mexico**

  The staff of our team-project, and especially Nathalie Sauer, collaborates with Professor Sergio Martinez (manager for research and development) on the subject of performance evaluation for the management of complex systems. The officialising of this collaboration throughout a contract granted by the Mexican government is under consideration.

- **Groupe DACIA and University of Pitesti - Roumania** The staff of our team-project, and especially Nidhal Rezg and Nathalie Sauer, collaborate with engineers of Dacia and the researchers of the Pitesti university. This collaboration concerns the simulation and optimization around the logistics and the maintenance.

- **University of Quisqueya (Haïti)**

  COSTEAM and University of Quisqueya collaborates in the scope of the service system control and engineering. Norly Germain, PhD student, works with a "co-tutelle" in this context.

- **University of Moncton - Canada**

  Nidhal Rezg is collaborating with Professor Gilles Cormier. This collaboration consists on developing new industrial integrated maintenance/production strategies.

- **USA NSF (I/U-CRC IMS), University of Cincinnati-USA**

  Since 2000, Kondo H. Adjallah has close collaboration with the USA NSF Industry/University Cooperative Research Center for Intelligent Maintenance Systems Center (I/U-CRC IMS), University of Cincinnati, Ohio. He invited Prof. Jay Lee, head of the IMS Center, on June 17-18, 2009, to deliver two days seminars on "Intelligent maintenance systems development" and on "dominant innovation strategy", to the laboratory members.

- **Federal Institute of Technology of Lausanne, Switzerland**

  Since 2000, Kondo H. Adjallah collaborates also with Dr. Dimitris Kiritsis, head of the LICP research lab, at the Swiss Federal Institute of Technology of Lausanne (EPFL). Dr. Kiritsis was invited on June 23, to deliver a seminar on "Emerging Technologies for Asset Lifecycle Management" to the laboratory members. This collaboration accounts for investigations on data collection process modeling and decision support to predictive maintenance.

6. Dissemination

6.1. Action for the research community

Kondo H. Adjallah has been invited to deliver keynote speech at the CCC 2010 (5th Colombian Congress on Computation), Cartagena, Colombia, April 14-17, 2010, on 'Approach of Data and Information collection for the Decision Support in Industrial Asset Management'. He has been also invited to deliver keynote speech at the ICECE'2010 (International on Electrical and Control Engineering), Wuhan, China, June 26-28, 2010, on 'About the extraction of relevant health information of equipments for optimizing their performances'.

Kondo H. Adjallah co-lead with Zineb Simeu Abazi from the G-SCOP lab, the Working Group MACOD of the GDR MAC, at national level. He is also leading the activities of the international cooperative research network for the Management of the Infrastructures of Development (ICRN MID), which involves research laboratories 7 High Education institutions in the world.

Most of the members of our project regularly participate in working groups of GDR-MACS (such as Bermudes, FL, RdP, CSP, INCOS, ORT, META, STP, GISEM). The GDR-MACS has vocation to federate the community of the researchers in industrial engineering, by extremely interdisciplinary nature.

Many members of the team are members of the ROADEF (French Operational Research and Decision Support Society). Nathalie Sauer is member of the new board of this society.

6.2. Member of program committees of journals or conferences

Lyes Benyoucef is Associate Editor in charge of 'Manufacturing and Service Operations' area of IJSOI (International Journal of Services Operations and Informatics), and editorial board member of IJBPSCM (International Journal of Business Performance and Supply Chain Modeling) and JOL (Journal of Operations and Logistics).

Lyes Benyoucef was also member of the international program committee of IEEE-INDIN'10 (8th IEEE International Conference on Industriel Informatics), IMS'2010 (7th International Symposium on Intelligent and Manufacturing Systems), ILS'10 (3rd International Conference on Information Systems, Logistics and Supply Chain), 6th IPROMS Virtual International Conference on Innovative Production Machines and Systems and MOSIM'10 (8ième Conférence Internationale de Modélisation, Optimisation et Simulation des Systèmes).

Sophie Hennequin was member of the program committee of ISC'10 (Industrial Simulation Conference), which has been held in Budapest, Hungary and of SAUM'10 (Conference on Systems, Automatic Control and Measurements) which has been held in Nis, Serbia.

Members of the team are reviewers this year for the following journals: International Journal of Advanced Manufacturing Technology, IEEE Transactions on Automatic Control, Computer and Education, International Journal of Production Research, Decision Support System, Discrete Event Dynamic Systems, International Journal of Production Economics, International Journal of Advanced Manufacturing Technology, Journal Européen des Systémes Automatisés, Discrete Optimization, etc.

Members of the team organize with the LGIPM (Laboratoire de Génie Industriel et Production de Metz) the 4th International Conference on Industrial Engineering and Systems Management, Metz, France, May 25-27, 2011.

7. Bibliography

Major publications by the team in recent years

[1] L. BENYOUCEF, B. GRABOT. *Artificial Intelligence Techniques for Networked Manufacturing Enterprises Management*, Springer Series in Advanced Manufacturing, ISBN: 978-1-84996-118-9, 2010.

[2] L. BENYOUCEF, M.-K. TIWARI. *Special issue on 'Advanced Metaheuristics for Integrated Supply Chain Management'*, Journal of Intelligent Manufacturing (Springer publisher), 2010, DOI 10.1007/s10845-010-0456-6.

[3] N. REZG, K.-H. ADJALLAH. *Special issue on 'Intelligent and collaborative maintenance in manufacturing'*, Journal of Intelligent Manufacturing (Springer publisher), 2010, vol. 21.

[4] R. K. SINGH, L. BENYOUCEF. *Special issue on 'Recent Advances in Service Operations and Logistics'*, International Journal of Services Operations and Informatics (Inderscience publisher), 2010, in press.

Publications of the year

Articles in International Peer-Reviewed Journal

[5] A. BENSMAINE, L. BENYOUCEF, Z. SARI. *Production-distribution network analysis using an intelligent simulator*, in "International Journal of Services Operations and Informatics", 2010, to appear.

[6] B. BIRREGAH, P.-K. DOH, K.-H. ADJALLAH. *A systematic approach to matrix forms of the Pascal triangle: The twelve triangular matrix forms and relations*, in "European Journal of Combinatorics", 2010, vol. 31, p. 1205-1216.

[7] A. CHAUBE, L. BENYOUCEF, M.-K. TIWARI. *An adapted NSGA-2 algorithm based dynamic process plan generation for a reconfigurable manufacturing system*, in "Journal of Intelligent Manufacturing", 2010, DOI 10.1007/s10845-010-0453-9.

[8] M. DAHANE, C. CLÉMENTZ, N. REZG. *Profitability conditions of subcontracting of a production unit under a joint maintenance and production policy*, in "European Journal of Industrial Engineering", 2010, (to appear).

[9] M. DAHANE, S. DELLAGI, C. CLÉMENTZ, N. REZG. *Development of maintenance and production strategies in a subcontracting environment*, in "International Journal of Production Research", 2010, (to appear).

[10] S. DELLAGI, N. REZG, A. GHARBI. *Optimal maintenance/production policy for a manufacturing system subjected to random failure and calling upon several subcontractors*, in "International Journal of Management Science and Engineering Management", 2010, vol. 5, p. 261-267.

[11] K. GUMASTA, S.-K. GUPTA, L. BENYOUCEF, M.-K. TIWARI. *Developing a reconfigurability index using multi-attribute utility theory*, in "International Journal of Production Research", 2010, DOI 10.1080/00207540903555536.

[12] A. HADJALOUN, I. KACEM, F. BENCHIHAOUI, N. REZG. *No-wait scheduling of a two-machine flow-shop to minimize the makespan under non-availability constraints and different release dates*, in "International Journal of Production Research", 2010, (to appear).

[13] Z. HAJJEJ, S. DELLAGI, N. REZG. *Optimal Integrated maintenance/production policy under a Variable Failure Rate depending to the production plan*, in "Journal of Intelligent Manufacturing", 2010, (to appear).

[14] A. KHATAB, N. REZG, D. AIT-KADI. *Optimal block replacement policy for a system operating under a random time horizon*, in "Quality and Reliability Engineering International", 2010, (to appear).

[15] A. KHATAB, N. REZG, D. AIT-KADI. *Optimum block replacement policy over a random time horizon*, in "Journal of Intelligent Manufacturing", 2010, DOI: 10.1007/s10845-009-0364-9.

[16] M. RADHOUI, N. REZG, A. CHELBI. *Integrated maintenance and control policy based on quality control*, in "Computers and Industrial Engineering", 2010, vol. 58, p. 443-451.

[17] M. RADHOUI, N. REZG, A. CHELBI. *Joint quality control and preventive maintenance strategy for imperfect production processes*, in "Journal of Intelligent Manufacturing", 2010, DOI 10. 1007/s10845-008-0198-x.

[18] M. REBAI, I. KACEM, K.-H. ADJALLAH. *Earliness-tardiness minimization on a single machine to schedule preventive maintenance tasks*, in "Journal of Intelligent Manufacturing", 2010, DOI 10.1007/s10845-010-0425-0.

[19] C. SAUVEY, N. SAUER. *Production-distribution network analysis using an intelligent simulator*, in "Journal of Intellgent Manufacturing", 2010, to appear.

[20] J. SCHUTZ, N. REZG, J.-B. LEGER. *Periodic and sequential preventive maintenance policies over a fite planning horizon with a dynamic failure law*, in "Journal of Intelligent Manufacturing", 2010, doi:10.1007/s10845-009-0313-7.

[21] R. K. SINGH, L. BENYOUCEF. *A fuzzy TOPSIS-based approach for e-sourcing*, in "Engineering Applications of Artificial Intelligence (international journal)", 2010, DOI 10.1016/j.engappai.2010.09.006.

[22] R. K. SINGH, L. BENYOUCEF. *Fuzzy logic and interval arithmetic based TOPSIS method for multi-attribute reverse auctions*, in "International Journal of Advanced Manufacturing Technology", 2010, to appear.

[23] S. TAMAYO, T. MONTEIRO, N. SAUER. *Perturbation analysis based-optimization for discrete flow model: a failure-prone manufacturing system with constant delivery time and stochastic demand*, in "International Journal of Advanced Operations Management", 2010, (to appear).

[24] J. M. TORO, S. HENNEQUIN, D. W. RAIGOSA, L. C. HEREDIA. *Fuzzy nonlinear regression model for ride quality railway systems*, in "International Journal of Universal Computer Sciences", 2010, (in press).

[25] Y. YEDES, A. CHELBI, N. REZG. *Quasi-optimal integrated production, inventory and maintenance policies for a single-vendor single-buyer system with imperfect production process*, in "Journal of Intelligent Manufacturing", 2010, DOI 10.1007/s10845-010-0423-2.

International Peer-Reviewed Conference/Proceedings

[26] K.-H. ADJALLAH, N. V. LOZANO, H. SNOUSSI. *Sensors Network Management for Health Condition Data Coverage on Large-scale Infrastructures*, in "A-MEST'10", Lisbon, Portugal, July 1-2 2010.

[27] M. ATLI, Z. ACHOUR, A. SAVA, N. REZG. *Control synthesis for partially observable marked graph subject to marking exclusion constraints*, in "MCPL 2010", Coimbra, Portugal, September 2010.

[28] M. ATLI, A. SAVA, Z. ACHOUR, K.-H. ADJALLAH, N. REZG. *Marking exclusion constraint for Petri net and control synthesis for partially controllable marked graph*, in "CIFMA 2010", Alep, Syrie, Avril 2010.

[29] M. ATLI, A. SAVA, Z. ACHOUR, N. REZG. *Control synthesis for partially controlled marked graph subject to marking exclusion constraints*, in "LSS 2010", Lille, France, Juillet 2010.

[30] S. AYED, S. DELLAGI, N. REZG. *Développement et optimisation d'une stratégie de maintenance dépendante du plan de production et tenant compte de droit rétractation*, in "MOSIM 2010", Hammamet, Tunisia, May 10-12 2010.

[31] S. AYED, S. DELLAGI, N. REZG. *Optimisation d'une politique de maintenance intégrée sous une contrainte de sous traitance avec construction de stock*, in "MOSIM 2010", Hammamet, Tunisia, May 10-12 2010.

[32] M. BENNEKROUF, L. BENYOUCEF, Z. SARI. *Problèmes de conception et pilotage des chaînes logistiques inverses: Etat de l'art*, in "MOSIM 2010", Hammamet, Tunisia, May 10-12 2010.

[33] A. BENSMAINE, L. BENYOUCEF, Z. SARI. *Intelligent simulator for production-distribution network analysis*, in "ILS 2010", Casablanca, Morocco, April 14-16 2010.

[34] Q. T. DUC, H.-A. LE-THI, K.-H. ADJALLAH. *DCA for minimizing the cost and tardiness of preventive maintenance tasks under real-time allocation constraint*, in "ACIIDC 2010", Hue City, Vietnam, March 24-26 2010.

[35] A. GORINE, N. SAUER. *Lower bounds and simulated annealing for job shop scheduling problems with blocking constrains*, in "ETFA 2010", Bilbao, Spain, Sptember 2010.

[36] C. D. JOSEPH, A. SAVA, N. SAUER. *Flexible manufacturing systems optimization approach based on labor cost minimization*, in "MOSIM 2010", Hammamet, Tunisia, May 10-12 2010.

[37] F. MALIKI, L. BENYOUCEF, Z. SARI. *Une approche d'optimisation-basée sur la simulation pour la conception d'un réseau de distribution stochastique multi fournisseurs*, in "MOSIM 2010", Hammamet, Tunisia, May 10-12 2010.

[38] M. REBAI, I. KACEM, K.-H. ADJALLAH. *Scheduling Jobs and Preventive Maintenance Activities on Parallel Machines*, in "10th ACS'10 WSEAS Int. Conf. on Applied Computer Science", Iwate, Japan, October 4-6 2010.

[39] C. SAUVEY, N. SAUER. *An efficient genetic algorithm for permutation flowshop problem with particular blocking*, in "MOSIM 2010", Hammamet, Tunisia, May 10-12 2010.

[40] J. SCHUTZ, N. REZG. *Determination of the Optimal Production Plan and Optimal Maintenance Plan following an Integrated Strategy for an Finite Time Horizon*, in "MOSIM 2010", Hammamet, Tunisia, May 10-12 2010.

[41] I.-B. SIDIBE, K.-H. ADJALLAH, A. KASSAMBARA. *Optimisation d'un plan de maintenance preventive application aux installations de l'EDM-SA*, in "MSAS'2010", Bamako, Mali, 01-07 Août 2010.

[42] I.-B. SIDIBE, K.-H. ADJALLAH. *Estimation des fonctions densité de probabilité de défaillance/ réparation par la méthode du noyau*, in "Symposium International sur la Maintenance et la Maîtrise des Risques", Rabat, Maroc, 15-17 avril 2010.

[43] I.-B. SIDIBE, K.-H. ADJALLAH. *Kernel method for estimating the density function of random processes in repairable components*, in "WCEAM'2010", Brisbane Queensland, Australia, October 25-27 2010.

[44] R. K. SINGH, L. BENYOUCEF. *Fuzzy multi-attribute decision making for e-sourcing*, in "IMS 2010", Sarajevo, Bosnia Herzegovina, September 15-17 2010.

[45] R. K. SINGH, L. BENYOUCEF. *Improved decision neural network-based approach for supply chain coordination*, in "CIRP ICME 2010", Naples, Italy, June 16-18 2010.

[46] H. SIOUD, A. SAVA, Z. ACHOUR, N. REZG. *Deadlock free control synthesis for partially controllable marked graphs*, in "LSS 2010", Lille, France, Juillet 2010.

[47] S. TAMAYO, T. MONTEIRO, N. SAUER. *Sanitary risk detection for a safer food chain management*, in "ILS 2010", Casablanca, Morocco, April 14-16 2010.

[48] W. TRABELSI, C. SAUVEY, N. SAUER. *Heuristic methods for problems with blocking constraints solving jobshop scheduling*, in "MOSIM 2010", Hammamet, Tunisia, May 10-12 2010.

[49] S. TURKI, S. HENNEQUIN, N. SAUER. *Perturbation analysis for continuous and discrete flow models: a failure-prone manufacturing system study*, in "MOSIM 2010", Hammamet, Tunisia, May 10-12 2010.

[50] S. TURKI, S. HENNEQUIN, N. SAUER. *Perturbation analysis for continuous and discrete flow models: for a failure-prone manufacturing system study*, in "MOSIM 2010", Hammamet, Tunisia, May 10-12 2010.

[51] R. M. VALLEJO, S. HENNEQUIN, K.-H. ADJALLAH, M. LODUI, G. DIAZ, L. CASTANEDA. *Fuzzy expert system for the control of a multicarburant internal combustion engine*, in "ETFA'2010 Congress", Bilbao, Spain, September 13-16 2010.

[52] Z.-H. WANG, K.-H. ADJALLAH. *Data and information collection process modeling for product lifecycle and health management*, in "PLM10", Bremen, Germany, July 12-14 2010.

[53] Z.-H. WANG, K.-H. ADJALLAH. *Lifecycle data collection process issues and modeling for equipment's health monitoring*, in "ICECE 2010", Wuhan, China, June 25-27 2010.

[54] A. ZOUGGARI, L. BENYOUCEF. *An innovative decision making tool for global supplier selection with order allocation*, in "CIRP ICME 2010", Naples, Italy, June 16-18 2010.

[55] A. ZOUGGARI, L. BENYOUCEF. *Supplier selection using a simulation-based fuzzy approach*, in "IMS 2010", Sarajevo, Bosnia Herzegovina, September 15-17 2010.

Scientific Books (or Scientific Book chapters)

[56] L. BENYOUCEF, X. XIE. *Supply chain design using simulation-based NSGA-II approach*, Springer publisher, 2010, In Multi-objective Evolutionary Optimization for Product Design and Manufacturing, Wang, Ng and Deb (Eds.), (to appear).

[57] Q. T. DUC, H.-A. LE-THI, K.-H. ADJALLAH. *DCA for Minimizing the Cost and Tardiness of Preventive Maintenance Tasks under Real-Time Allocation Constraint*, Lecture Notes in Computer Science, 2010, vol. 5991, p. 410-419.

[58] N. REZG, S. DELLAGI. *Intelligent integrated maintenance policies for manufacturing systems*, Springer series in advanced manufacturing, ISBN: 978-1-84996-118-9, 2010, p. 315-339, In Artificial intelligence techniques for networked manufacturing enterprises management, L. Benyoucef and B. Grabot (Eds).

Research Reports

[59] M. ATLI, Z. ACHOUR, A. SAVA, N. REZG. *Supervisory control of timed-place marked graph based on marking exclusion constraint*, Laboratoire de Génie Industriel et Production de Metz, 2010.

[60] M. ATLI, A. SAVA, N. REZG. *A method for air traffic rescheduling based on ground delay, rerouting and flight canceling*, Laboratoire de Génie Industriel et Production de Metz, 2010.

[61] E. GOMEZ, S. HENNEQUIN, N. REZG. *Optimization of the maintenance policy: an IPA approach*, Laboratoire de Génie Industriel et Production de Metz, 2010.

[62] M. KAMMOUN, A. SAVA, N. REZG. *A Modeling and rescheduling method for air traffic management based on binary decision diagram*, Laboratoire de Génie Industriel et Production de Metz, 2010.

[63] R. MARIN, S. HENNEQUIN, K.-H. ADJALLAH, M. LODUI, G. DIAZ, L. CASTANEDA. *Fuzzy expert systems for a multi-carburant engine*, Laboratoire de Génie Industriel et Production de Metz, 2010.

[64] H. SIOUD, A. SAVA, Z. ACHOUR, N. REZG. *Deadlock free supervisor for partially controllable and observable marked graph*, Laboratoire de Génie Industriel et Production de Metz, 2010.

[65] D. TOBON, S. HENNEQUIN, F. BOTERO, L. C. HEREDIA, N. REZG. *Management des risques basé sur la logique floue pour la maintenance d'une turbine Francis*, Laboratoire de Génie Industriel et Production de Metz, 2010.

[66] S. TURKI, S. HENNEQUIN, N. SAUER. *Perturbation analysis based-optimisation for a failure-prone manufacturing system with constant delivery time and stochastic demand*, Laboratoire de Génie Industriel et Production de Metz, 2010.