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Digital Enterprises: A national R&D project in Hungary

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Abstract

Today's complex manufacturing systems operate in a changing environment rife with uncertainty. The performance of manufacturing companies ultimately hinges on their ability to rapidly adapt their production to current internal and external circumstances. On the base of a running national research project on digital enterprises and production networks, the paper illustrates how the concepts of intelligent manufacturing systems and digital enterprises can contribute to the solution of the above problems.

Keywords:

Digital enterprises, production planning and scheduling, manufacturing monitoring and control, constraint-based optimization, simulation, multimedia applications

1 INTRODUCTION

Manufacturing systems of our epoch work in a fast changing environment full of uncertainties. Besides internal factors (e.g. malfunctions, break downs), the main external reasons of uncertainties are:

- fast increasing and diversified customer demands,
- increasing role of the one-of-a-kind production, fast sequences of new tasks,
- increase of the number and speed of communication channels,
- appearance of new technologies,
- fast changes in the partners (suppliers, distributors, customers, purchasers),
- instability of market circumstances (as e. g. the hectic changes of raw material prices).

Increasing complexity is another characteristics which shows up in production processes and systems and in enterprise structures as well.

The concept of the digital enterprise, i.e. the mapping of all the important elements of the enterprise processes by means of information technology tools gives a unique way of managing the above problems. However, the management, the optimal or near to optimal exploitation of the available huge amount of information cannot be imagined without the effective application of the methods and tools of artificial intelligence.

The partners in the project on Digital Enterprises, Production Networks supported by the National Research and Development Program (NRDP) in Hungary, build a well balanced "academia-industry" cluster: GE Hungary Rt., as a big manufacturing enterprise, MT-System Ltd. as an information technology SME are on the industrial side, while the academia is represented by the Budapest University of Technology and Economics, the Miskolc University, the Computer and Automation Research Institute, Hungarian Academy of Sciences.

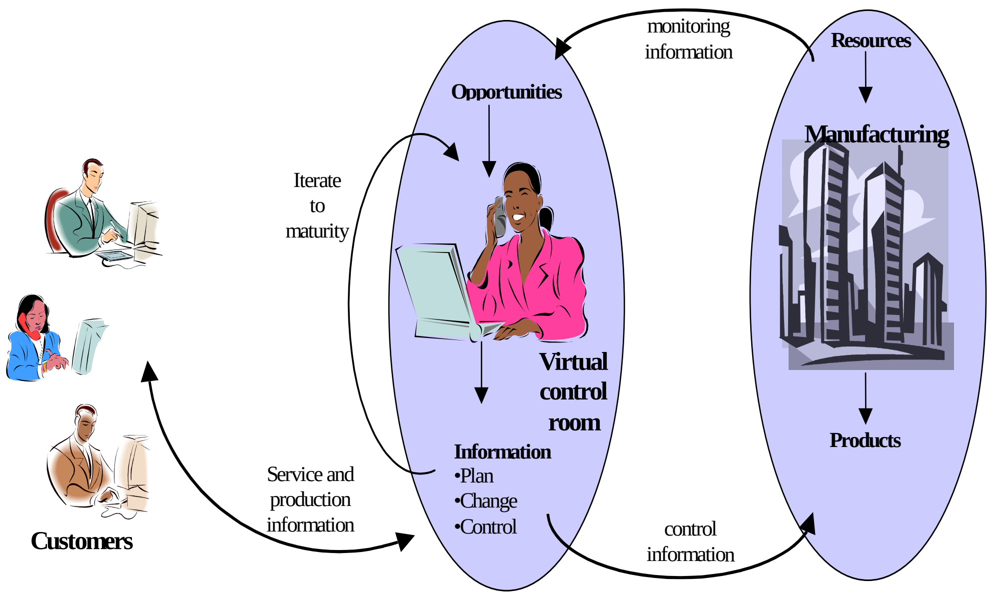

Figure 1: Illustration of the concept of the NKFP project on digital enterprises

Figure 1 illustrates the concept of a digital, distributed enterprise representing the framework for the research. The project has the following - partly overlapping - main directions to be treated in a comprehensive way:

- Management and scheduling of large-scale projects.
- Tele-presence and interactive multimedia.
- Monitoring of complex production structures.

The national R&D project has been started to make all the important production-related information available and manageable in a controlled, user-dependent way by the efficient application of information and communication technologies. The development and application of intelligent decision support systems will help enterprises to cope with the problems of uncertainty and complexity, increase their efficiency, join in production networks and to improve the scope and quality of their customer relationship management.

2 PROJECT MANAGEMENT AND SCHEDULING

2.1 Constraint-based optimization

Our central claim is that production management calls for a new approach that integrates – or at least provides an interface for – the business and production-oriented activities in manufacturing. The upward (towards ERP) and the downward (towards Manufacturing Execution Systems, MES) integration requires expressive models and extremely efficient solution processes [1].

The problem – which has both planning and scheduling aspects – can be solved only if we can find an appropriate match between the problem formulation, the available domain knowledge, the representation as well as the efficient utilization of this knowledge. In our opinion, finding this match is now possible via the application of the recently emerged paradigm of constraint programming (CP). CP provides, on the one hand, expressive and flexible declarative representation techniques of Artificial Intelligence (AI), and, on the other, efficient reasoning and search methods that combine the results of Operations Research (OR) and AI. This integration can improve both the representation power and solution quality especially in terms of efficiency, scalability and optimality [3,6,8].

As the core of our methodology, we need a factory model: a computational representation of the structure, activities, processes, information, (material and financial) resources, workers, constraints, goals and the objectives of the factory. This model should represent what is planned and what has happened in order to provide information to decide on what might and should happen. Our factory model uses basic entities and relationships. The main concepts of the model are related to

- products and production technology,
- production demand, and
- production resources.

Relationships are expressed by constraints that link products, activities, resources and time. Considering their origin, the constraints are

- model constraints that express the semantics of the model,
- technological constraints (such as activity precedences and resource requirements), and
- operational constraints deriving from the internal rules and policies applied when running the production.

Further on, we have various criteria (such as minimization of makespan, flowtime, tardiness, WIP level; maximization of throughput, etc.) to evaluate the alternative behaviors of the factory. The problem is to determine the timing of activities and to assign resources (human, material and financial) to the activities in a way that fulfils the constraints as far as possible and approaches some optimization objectives. Due to the complex system of constraints and criteria, problems typically have multiple resolutions.

2.2 The role of simulation

The constraint-based factory model, however, can hardly account for all the uncertainties. Though, we can include such uncertain factors into an appropriate simulation model [2]. Discrete event simulation has been considered for a long time an enabling technology for digital factories. In this part of the project, it will validate the results of the constraint-based model.

Hence, there are two main components: a constraint-based optimizer generates (close-to) optimal plans and schedules, and a simulator checks and evaluates plans and schedules via discrete event simulation (see Figure 2). Constraint-based optimization can work with clear-cut model and optimization criteria. By developing appropriate search methods, close-to-optimal solutions are generated within reasonable time bounds. In turn, the solutions generated are verified via simulation, in face of uncertainties as well.

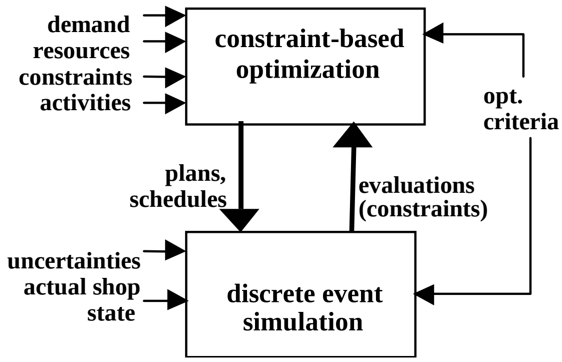

Figure 2: Constraint solving coupled with simulation

Decision-makers, even if they have strategic, big-picture expertise are often unable to effectively cope with conflicting interests and the complexity of detailed solution development. Hence, a model of collaborative production management has been established that supports an iterative, evolving process of problem understanding, requirement determination, conflict resolution and solution refinement. An important issue is to help end-users to solve complex, eventually even over-constrained and/or multi-criteria optimization problems with possibly conflicting criteria. The challenge of mixed-initiative, exploratory problem solving is to allow the end-user to explore the solution space interactively, eliciting information about solutions and potential solutions, which enables them to select the very best solution for their own purposes. The above architecture will be a basis for a solution process like this. Note that it provides a bridge between the traditional ERP and MES systems, too.

2.3 Planning and scheduling applications

We apply the constraint-based modeling methodology and take the above combined solution approach to solve problems of industrially relevant size and complexity. The target application domains have, however, very different features. In one of the cases, projects cover the complete life-cycle of one-of-a-kind products of great value. Hence, the set of activities consists of product and technology design, process planning, manufacturing, assembly, warehousing, packaging, delivery, installation and services. The activities are typically overlapping and can be pre-empted. Activities can share resources, and resources can be used at various intensities when performing the activities. Finite capacity resources can be supplemented by external capacities. Capacity extension incurs, of course, considerable extra cost. Production planning should be carried out with a medium term look-ahead. Since neither the demand nor the resource availability can be known completely for this period, we have to cover such uncertainties and do planning in an incremental way. Due to external and/or internal changes time and again there is a need of re-scheduling the activities of running projects as well.

In another problem domain components are produced in small sets. The technology includes manufacturing, testing and assembly operations. Since quality assurance is a key issue, tests may result in extra adjustment operations. Hence, production technology contains a momentum of uncertainty in itself. Though working basically with forecasted demands, production planning has to account for unpredicted orders as well. Due date observance is an absolute requirement, hence planning cannot be separated from detailed scheduling of shop floor activities. Scheduling must be based on up-to-date information. The tracking of jobs is already solved by an MES system. Just as in the other application, the planner and scheduler system should support mixed-initiative decision making.

3 TELE-PRESENCE AND INTERACTIVE MULTIMEDIA

No matter how sophisticated and automated a design / production system can be, human expertise is still needed in all phases of design/production. Due to the globalization and the international integration of production resources and other facilities, sites are scattered in space, around the globe. This implies that design engineers, testing and evaluating experts, end-user customers are located far away from each other and from the premises of the design, manufacturing, production, testing facilities. Not only larger factories but also small and medium enterprises face this situation.

Our research activities must focus on developing new solutions to allow human experts to get an open interface to all design, planning, production, testing and end-site environment any time and anywhere. Information in this general meaning includes text, numeric data, figures, pictures, video, sound - used and applied in an integrated manner, and referenced as multimedia. Further senses, such as tactility could be included in the advanced man-machine or human-machine interfaces of the next generation.

Research efforts cover the methods for tele-presence, remote or tele-work, and all related issues, far more than just video-conferencing. The integration of multiple sensors, application of mobile and wearable computer platforms (Figure 3), the implementation of broadband multi-channel communication links among human beings and production means that new software environment and application frameworks are needed which offer high efficiency and reliable production. The on-line and canned video information, integrated with on-line and archived production data and real-time logistics must be managed by a reliable, distributed multi-media database, because product and production data of individual products must live for several decades, during which time the IT hardware environment will definitely get replaced several times with the upgrades of new generations of computer systems.

Figure 3: Wearable display to allow virtual reality

Research must also cover the problems of safety. The two most relevant areas include the reliability of up-stream information, i.e. the source data sets and access authorization. Whenever important business decisions are based on distributed information, fail-safe technologies and system elements are to be implemented. Open Information Systems will be developed and implemented. Interactive multi-media will offer bi-directional information flow among participants, and IT systems. This way experts, staff and customers will have different authorized access to on-line and canned visual, multimedia information or data.

Design engineers and customers will have the right tool to see and to be virtually at the spot of production (Figure 4)., at the machines, facilities, resources of the plant, anywhere around the globe. The machine operators will also have full multimedia based access to the virtual product images, and virtual production sequences generated by the animation/simulation packages of CAD engineers. End-users or customers could have visual access and tele-presence services to monitor the production phases related to their product (mostly in the case of so called one-of-a-kind products the customer likes to see them during production, test and/or packaging, etc.).

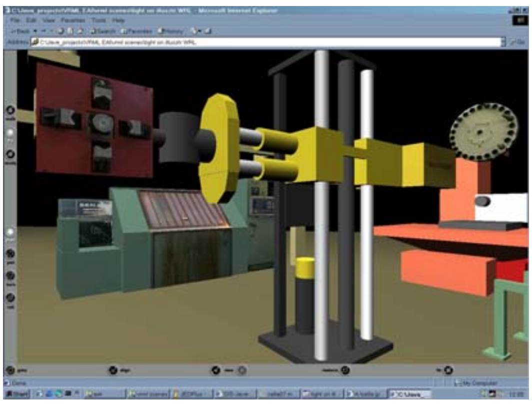

Figure 4: Real-life and animated environment of a CIM pilot system

Since most products and their production parameters are to be kept for a long time, the multimedia database has to supply information during the whole life-cycle of the product. Large and one-of-a-kind products (e.g. turbines) will serve several maintenance and repair phases, and should be designed for recycling as well. Thus, the product information attached to a product should also contain dismounting or discarding guides.

The basic elements of the technology to implement the tele-presence service are almost readily available, but before they are applied to our specific areas, research must be conducted to avoid technical, technological pitfalls and to lower risks of human mistake.

4 MOMITORING OF COMPLEX PRODUCTION STRUCTURES

Production monitoring is a special field, because

- the production process is already fully planned and the main task is to execute the processes as determined,
- changes and disturbances arise during the production - monitoring has to track and control these disturbances and their effect on the production processes,
- the high number of information, characterizing production processes,
- complexity of production processes,
- partially understood relations among these data.

Advanced monitoring systems should support the measuring and processing of a large amount of data (e.g. 5-10000 samples per second) and give appropriate information for:

- the control level to initiate necessary intervention into the production in order to prevent additional losses and damage,
- personnel to make necessary further measures, maintenance activities,
- the management level about the operation of the production system.

In addition to the above issues, the system to be developed is expected to solve many of the tasks enumerated above, more exactly, by using the appropriate signal processing, artificial intelligence, machine learning, data-mining and visualization techniques. Hence, it will contribute to the reliable, efficient functioning of the plant, providing maximal support to the operators.

4.1 Research objectives

In the CIRP survey on the developments and trends in control and monitoring of machining processes, the necessity of sensor integration, sophisticated models, multimodel systems, and learning ability was outlined [5].

Artificial neural networks (ANNs), neuro-fuzzy (NF) systems are general, multivariable, non-linear estimators, and therefore, they offer a very effective process modeling approach.

Because of the great variety of monitoring parameters mentioned above, it is very difficult to build up a comprehensive model for a production process. Identifying parts that can be modeled independently is one of the main issues of modeling. A very important goal of the research is to automatically determine these individual parts, based on the monitoring parameters.

Naturally, the high number of measurements of monitoring parameters causes a certain amount of incomplete data, their appropriate handling constitutes another important subject of the project [7].

Monitoring systems are expected to give information more and more reliable for the user in a comprehensive way. Finding appropriate techniques to present and highlight important manufacturing information is a fundamental goal of this part of the project, as well.

In order to accelerate the development and to enlighten the practical application of monitoring systems, appropriate, monitoring–related simulation of the production plants is also envisaged.

5 SUMMARY

The paper outlined the main aspects of a national R&D project in Hungary on digital enterprises, production networks. Intelligent decision support systems will be developed in order to help enterprises to cope with the problems of uncertainty and complexity, to increase their efficiency, to join in production networks and to improve the scope and quality of their customer relationship management.

6 ACKNOWLEDGMENTS

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