Concept of the System for Optimization of Manufacturing Processes

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Abstract

This paper deals with the optimization of manufacturing and logistics processes with the support of progressive computer simulation approaches. It briefly discusses systems and tools developed at University of Zilina, from the Laboratory of Intelligent Systems ZIMS, through the use of emulation and software as a service, to own computer applications based on Genetic Algorithms (GAsfoS, GAsfoS2), scheduling of custom production (SSEM) and metamodelling (SAGME). Alignment of developed tools is represented in system OSMAP.

1. Introduction

At a time of economic crises, constantly changing market conditions, it is difficult to survive in so competitive environment. Hereby increasing, and often changing customer's requirements and seriousness generate a big pressure on manufacturers and businessmen, and company has to adapt to this changes if it wants to survive. Production is more frequently customer orientated in order to fulfil requirements of wide spectra of customers and to satisfy their individual demands. Furthermore production volume is changed, thanks to actual market situation and customers in an effort to save. Not only production but also scheduling and production control have to adapt to this.

There exist several solutions and tools that help to find right setup of a system and to solve complications that occur within production process. These are progressive approaches based on computer simulation that help to optimize production and logistics processes, but it is also possible to use them in non-manufacturing sphere. In the next section we will introduce particular approaches and design of integration of these solutions into one system OSMAP. At first it is necessary to identify production systems and their development in the future in order to regard their characteristics at proper design. In respect of complexity of today's production systems, range of potential solutions and their valuation, support of means of artificial intelligence is used.

2. Production Systems

In order to survive in global environment it is needed to plan, control and continually improve production processes. Therefore a company has to apply global strategy of its development and to ensure lodgment at the market. Main characteristics of world class enterprise are vintage and motivated staff, zero failures, low fluctuation, low supplies and down-times, extremely short setup times, and continuous improvement of enterprise processes.

Apart from many innovation generating, rapid preparation and initiation of production is necessary because that one who comes into the market earlier gets advantages (new market segments, pricing, etc.). Therefore a modern technical preparation should integrate constructional, technological and projective production preparation, team organization of work, simultaneous engineering, approaches and techniques of system engineering (projection control, simulation), strong computer support (CAPP, means of simulation).

The prognosticators marked digitization and digital technologies as the main driver of productivity growth in 21th century (Manufuture, 2004). In robust way they are also applied in manufacturing corporations. Nowadays productivity is grown also with help of artificial intelligence that moves from laboratory conditions to practice specifications, begins with sensors, control units, through systems for image or sound identification, pending autonomous robotic workstations used e.g. in automotive industry.

2.1. Intelligent Manufacturing Systems

Intelligent system recognizes and understands reasons of changes and uses this knowledge for learning. Repeated system's inputs deepen its learning. Besides people and animals belong to intelligent systems also intelligent machines. They are more frequently used in industry practice and they help to eliminate human deficiencies.

Intelligent manufacturing system (IMS) is defined as system with autonomous ability to adapt unexpected changes, inter alia also changes of market, technologies, public demands, etc. The main properties of IMS are:

- systematization of all elements in production and its set-up,
- flexible integration of whole company in order to optimal cooperation between man and intelligent technical equipments,
- usage versatility,
- self-education and adaptability,
- information directness,
- spreadness.

Efforts in IMS area are developed also in Slovakia, at the University of Zilina.

2.2. ZIMS

Zilina Intelligent Manufacturing System (ZIMS) is the initiative of the University of Zilina that supports innovation trend named IMS in cooperation with practice. ZIMS is designed in a single version for the purpose to represent advanced production systems and simultaneously to allow experimentation and another research in intelligent manufacturing systems area.

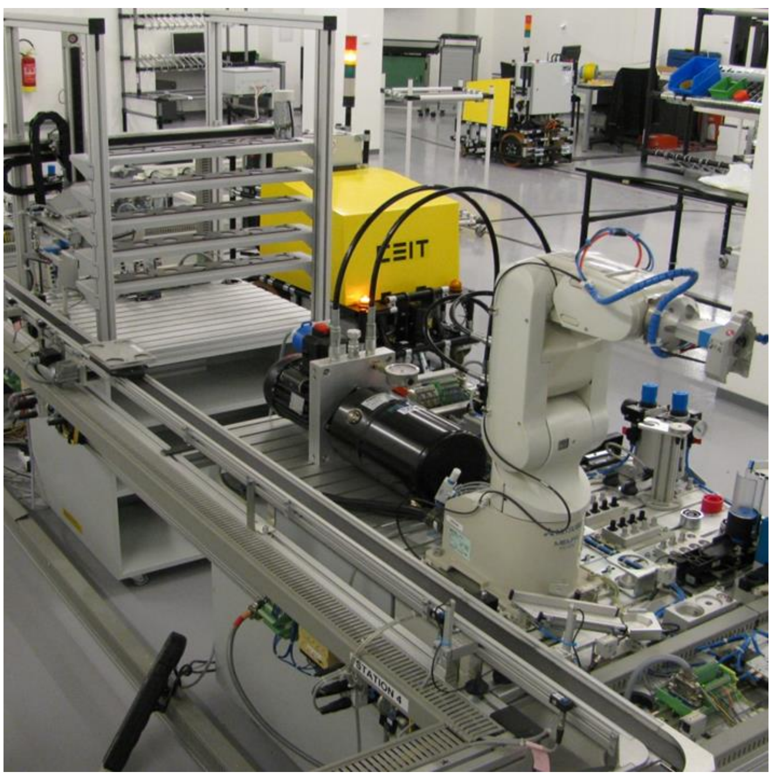

Figure 1: Workstation of automated assembly in ZIMS (Gregor,M. at all, 2011)

It includes specialized workstations needed for development and creation of a product:

- constructional workstation for a product design,
- scanning workstation, projection system CEIT-table used for planning of production system in virtual reality,
- simulation station,
- ergonomic station with various endurance tests,

- fully automated assembly line,
- camera control station,
- working machines are planned.

Furthermore in this laboratory, there are automated guided vehicles developed by the Central European Institute of Technology (CEIT) in cooperation with the University of Zilina. Nowadays ZIMS uses technologies of partners' organizations Siemens, Festo, Mitsubishi, CEIT. On the ZIMS development participate further industrial partners successful in innovation.

Our research and development uses approaches for designing and testing of new products and production processes. These approaches make use of rapid prototyping technologies, digitizing, virtual reality and simulation. Virtual reality is possible to use in the area of product development, designing of production processes, workstations, production systems, systems for planning and production control, etc. Nowadays Digital Factory represents the most progressive approach for complex, integrated designing and simulation of products, production processes and systems. Tools of Digital Factory used at our department are described in (Hnát, 2011).

Concept of Digital Factory is based on three elements:
- digital product with its static and dynamic aspects,
- digital production planning,
- digital production with application of planning data in order to increase efficiency of enterprise processes.

According to prognosticators computer simulation becomes dominant technology in 21th century. Gregor (2012) It is described in the following section.

3. Simulation Optimization

Simulation as a supporting tool for decision making process, analysis, optimization and forecasting is mainly used for process optimization, planning and process control, projection and analysis of production systems, beating up logistical conceptions, staff training, etc. The heart of simulation is experimentation with model of a system and so looking for problem's solutions of real systems, or looking for suitable layout of conceptual system. Satisfactory results are then applied on the real system.

3.1. Optimizing System for Manufacturing Processes – OSMAP

Each of tools mentioned below presents advanced approach in simulation optimization. They provide answers to frequently asked question like: "What happens if…", "Where is it possible to save?", "Is it possible to meet the deadline and price?", "Why do we have higher costs than competitors?", "What is a reason?", etc.

The tools *GAsfoS2*, *SSEM*, *SAGME* are strong means of optimization, however their unification and interconnection forms complex system for optimization of production and logistical processes. *OSMAP* combines under "one roof" all created modules and helps to find solution close to optimal or directly optimal. Its fundamental structure is displayed in the Figure 2.

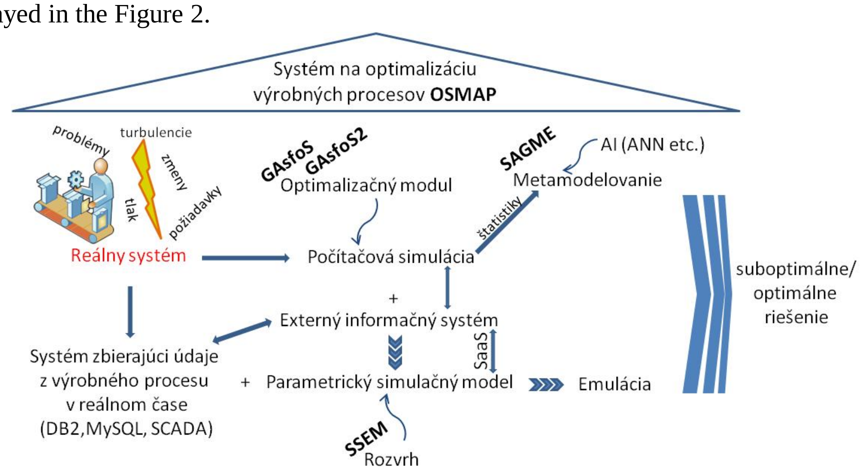

Figure 2: Concept of the OSMAP system

3.2. Parametric Simulation Model

Acceptable result is extreme value of optimal criteria (i.e. either selected objective function or values of some numeric characteristics of manufacturing system) and it can be achieved by means of suitable harmonization of system's sources possibilities. The most commonly used objective and universal optimal criterion in production systems is/are the total production costs. The conventional off-line optimization consists in sequential alternating of input values in simulation model, consecutive simulation runs realization after each variation, and consequences of system changes evaluation. Setting of input factors' values is possible to perform without deep knowledge of simulation software, namely in the environment of an external information system (e.g. MS Excel). Value variation is automatically loaded into created simulation model and simulation run can be executed. Experimental results, numeric characteristics of system (e.g. average throughput time, production performance, capacity utilization, etc.) are retransferred into external information system, and on this basis corrective arrangements are accepted. This process is repeated until satisfying result is achieved. Sample of different variations of simulation model of real production system and results of its runs are presented in (Štefánik, 2005).

3.3. Reality And Simulation Model Integration

In the case of connection of external information system, as well as simulation program, with the real system we are talking about emulation. (Palajová, 2011) Production data mining is executed with the help of database system (MySQL, DB2, SCADA …) that enables simple data handling. Such solution also provides information in a real time and therefore enables to simulate and solve just occurred problems. Other advantage is set-up option of the real system from computer. Thereby we can determine variety influence of regulation in production by virtual model with a direct integration to the real production system. The emulation environment enables to:

- monitor the manufacturing or logistics systems,
- evaluate collected data in a real time,
- update model on the base of real system's data,
- perform experiments on accurate, updated and verified simulation model.

At our department the real production system was replaced with lego modular production system and later will be tested in ZIMS environment.

This approach is practically appropriate for variation of current problem's solution and optimization of production and logistics processes. However, major problem still remains a high purchase cost of simulation software and tools necessary required for advanced approaches in simulation, especially for small and medium enterprises.

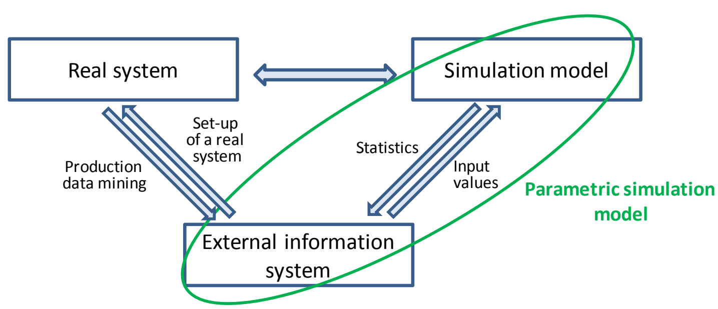

Figure 3: Emulation

3.4. SaaS

One possibility how to eliminate problem of expensive solution is exploitation of cloud computing. The target is delivering software as a service (SaaS), in this case simulation software. It means that customer's data are stored in "cloud" in databases placed on server on the internet, and users can access to them through web browser or client application and use them practically anywhere. It means that company doesn´t need to own simulation software and it saves costs connected with a purchase of special software and with staff training. The company pays just for the use of software and it get off hand for service and maintenance of program. The substance of simulation software as a service is that customer just opens excel interface and sets up values of desired production factors. These values are loaded into parametric simulation model placed on server of external company. Right there simulation runs are executed and statistical results are automatically sent back to customer. On their basis customer decides whether and what arrangements will they accept.

3.5. GAsfoS2

The simulation optimizers that can be a part of simulation program or can be in-programmed help on a large scale for simulation optimization. Our application named GAsfoS2 (designed in Heglas (2011)) is based on genetic algorithm (GA) and it is able to optimize whatever production system. It enables to start simulation model, set-up simulation run, start simulation, set-up genetic algorithm and consequently optimize production system. These acts are executed in user operating environment GAsfoS2. The library supporting work with GA is a part of *GA core* that forms the basis of program *GAworker*. Communication interface between *GAworker* and simulation program is *Valuator*. Operation principle rests in evaluation of each generation, results of individual simulation runs are noted down and evolution continues while one of two conditions is fulfilled:

- number of generation has been achieved,
- required value of optimization criteria has been achieved.

GAsfoS2 is modified application of GAsfoS designed by Škorík (2009), with the more general usage. It may be used for whatever simulation model but currently it uses of only one GA.

3.6. Simulation And Scheduling – SSEM

Raising productivity of labor and activities that are associated with the execution of production become the key parameters required to be at maximum level. The important task in production on operative level is the generation of a manufacturing schedule. In general, scheduling problem is given by limited products set that are manufactured on limited number of production machines. For solving of these problems are besides exact and heuristic methods increasingly used meta-heuristic methods and simulation techniques. There also exists several planning or ERP systems that generate production schedules. However they are limited enough and dedicated to coarse planning. On the other side, Advanced Planning Systems (APS) accept different constraints and use optimization algorithms but their purchase is connected with high costs. Therefore a modular system for scheduling of custom manufacturing with support of simulation and evolutionary methods was created. It was named *SSEM* (Scheduling using Simulation and Evolutionary Methods) (Figa, 2012) and it consists of three parts:

- schedule generation or scheduling with the use of preferred rules that have common base,
- schedule evaluation by means of parametric simulation model according to the selected criteria,
- optimization by means of evolutional methods in order to achieve better solution.

The basis is communication of simulation software with schedule generator, optimizing module (GA) and change calendar. Input for parametric simulation model is primary schedule. After simulation run objective function is calculated by selected preferred rule. Optimizing module provides set of realizable solutions of simulation model in term of selected criteria power with the help of genetic algorithm. Result of optimization is optimized schedule according to specific criteria on the base of fitness function. Obtained facts from simulation model or schedule generator are apportioned into change calendar and on the base of managing instructions production schedule is generated.

3.7. Simulation Metamodelling – SAGME

In a state of simulation results acquiring it is possible to simplify, combine inputs from simulation, and eventually eliminate those that have shown to be needless. This enables so called metamodels or models of simulation models that substitute simulation data with function curve and reliably approximate them. This approach was named as *approximation control*. It is based on replacing of empirical data with suitable type of theoretical function that realistically describes authentic data acquired from a system or from the simulation. Our system for automatic generation of metamodels *SAGME* (Palajová, 2012) was created for such purposes. The system *SAGME* consists of five modules:

- module for data collection,
- module for variables' dependences detection,
- module for calculating of metamodel parameters,
- module for error calculating,
- module of total reports.

The *SAGME* system enables well-arranged simulation results in form of contingent tables and charts, recovery factors with the strongest influence on monitoring responses, function parameters accounting, metamodel validation in regard to simulation model, and all received results summarization into synoptic charts. On their basis it is possible to define approximation rate of accuracy, to accept metamodel or find better solution.

There is possible to use artificial neural networks (ANN) for simulation data substitution because they are universal function approximator. For discovery correlation of simulation outputs to corresponding inputs, ANN with teacher or ANN with supervised learning is used. The substance is the attempt to teach ANN behaves in monitored system way and consequently to apply acquired rules on any input value. This principle was demonstrated in a real model described in (Gregor, 2012; Palajová, 2012). The effect of downtimes appearance and repair times on average throughput time was monitored.

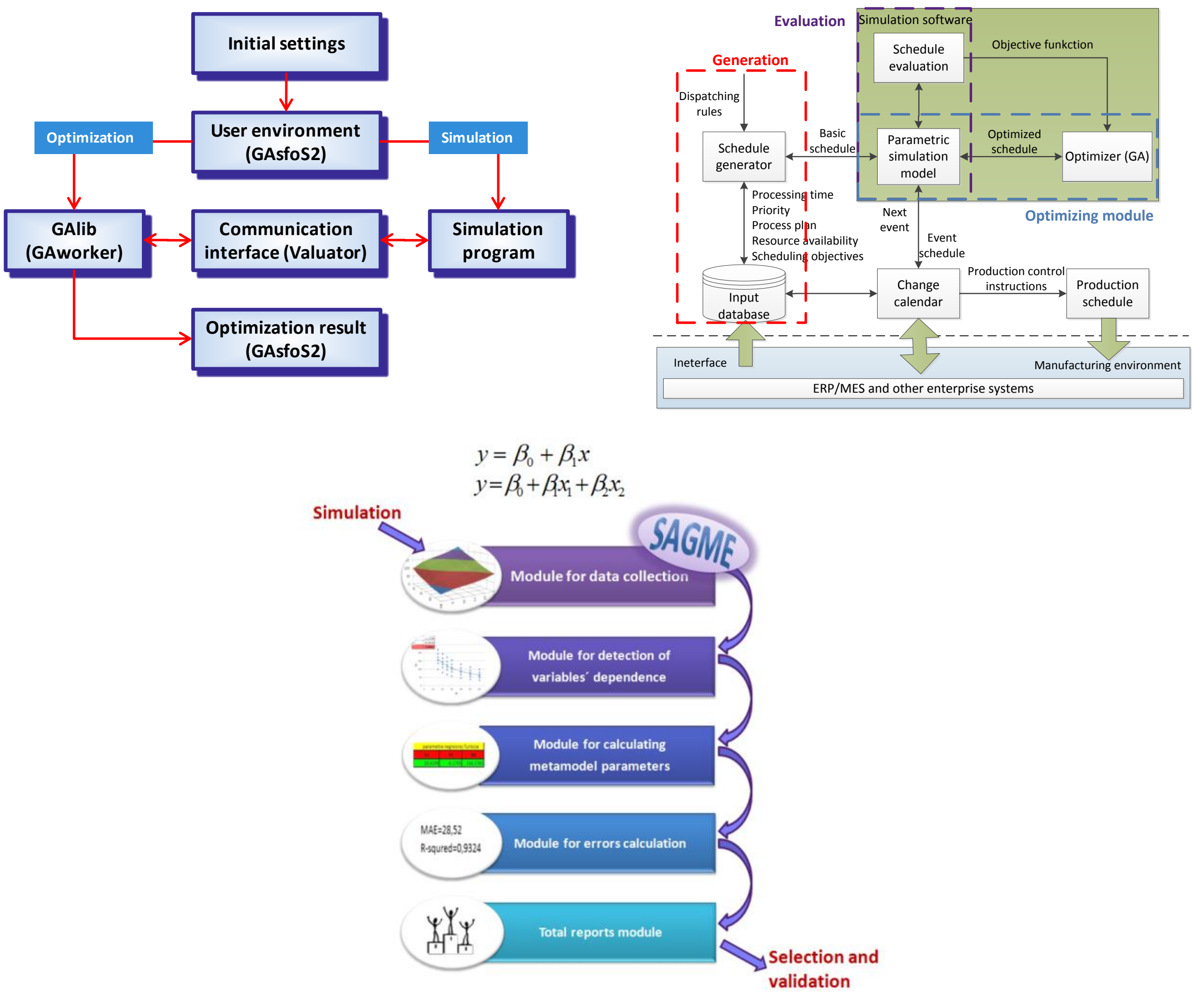

Figure 4: Structures of applications GAsfoS2, SSEM, SAGME

5. CONCLUSIONS

These progressive approaches afford opportunity to use simulation in terms of practice easier. They can flexibly respond to customer's requirements and provide them a tailored service, and enable rapid use of simulation in the commercial sector, not only in terms of research. The above mentioned progressive simulation approaches allow:

- to easily enter own values of elective variables (loading input data from an external source),
- to operate parametric simulation model by managers and operators in production shop,
- to test various managing and optimizing methods without deeper knowledge of modelling and simulation methods, and simulation software,
- to execute simulation runs and process optimization without possession of simulation software,
- to find the best solution of company problems in a very short time,
- to save financial resources.

The approaches described in this paper focus in the improvement of companies' interest in simulation of manufacturing and logistics systems.

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