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WEB-BASED VALUE STREAM ORIENTED SIMULATION OF PRODUCTION CONTROL

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ABSTRACT

Production control faces the challenge to cope with high market dynamics and high complexity in production structures. Therefore, simulation is often used to configure production control properly. Today, the generation and configuration of these simulation models need expert knowledge and cause high costs. The presented approach shows how simulation models can be generated in short times and without expert knowledge within simulation. Therefore a web-based platform is configured, which enables the employees to generate a simulation model of the production. Since the structure of these simulation models is modular, the employees can upload input data and chose different strategies of production control by themselves in order to optimize their current production control. By integration of employees within the simulation generation process, the acceptance in simulation and in simulation results increases.

1 INTRODUCTION

Nowadays manufacturing companies are more and more faced with complicated production structures and a wide range of products caused by individual and high customer demands. The aim is to combine a high level of quality with short and reliable runtimes and as low costs as possible (Steven 2007).

Dealing with this complexity is a big challenge for production planning and operations management. There is a need to compare different scenarios and their impact on relevant key data such as costs, runtimes etc. One way to handle this issue is to use simulation. Simulation is applied to ensure the feasibility of planning concepts, to discover rationalization possibilities and to assist in decision making. There is a wide range of simulation paradigms in the area of production and logistics. In the planning phase, simulation is used to support the planning and dimensioning of production systems and the design of process alternatives and control strategies (Lödding 2010). In the operation phase it visualizes and optimizes complex processes to assist in management information systems and in decision making. Furthermore, virtual commissioning as emulation for the real system has become more important in the recent past (Boer 2008).

Another trend is to incorporate existing web technology. Using web-based simulation tools provides close monitoring for the evolution of the simulation project, enhances the coordination and communication of the simulation participants, identifies and resolves conflicts that may arise in the simulation team and creates virtual simulation expert communities (Kehris 2009). Using one platform with the possibility of choosing one of various interfaces encourages the collaboration of several participants and different aspects as well as point of views can be combined.

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However, the modeling process of high quality models which are verified and validated is time consuming and requires a lot of expertise in different knowledge areas including computer sciences, economic sciences, mechanical and industrial engineering and statistics. Therefore the usage of simulation is linked with high costs. That is an issue, especially for smaller and middle sized companies.

Consequently the aim of this paper is to introduce a web-based simulation model which supports operators within the configuration of production control.

2 STATE OF THE ART

In order to reduce the costs for the generation of simulation models, which are supportive to configure and optimize the production control, an automatic generation of simulation models is used. In such approaches of automatic (or semi-automatic) model generation, a simulation model is not created manually but is generated from external data sources (Eckhardt 2002).

There are different possibilities to classify the approaches for semi-automatic model generation. Eckhardt (2002) divides the approaches into three categories:

1. Parametric approaches: Models are generated from existing simulation building blocks stored in simulation libraries, which are selected and configured based on parameters.
2. Structural approaches: Model generation is based on data describing the structure of a system typically in the form of factory layout data from relevant CAD-systems.
3. Hybrid-knowledge-based approaches: These approaches combine artificial intelligence methods with both of the above approaches. Examples of artificial intelligence methods being used are data mining or neuronal networks. They facilitate e.g. pattern recognition in production data which have to be represented within the simulation (Strassburger 2010).

According to Strassburger (2010) most of today's approaches are hybrid because of using both, parametric and structural data.

The difficulty in modeling complex manufacturing systems is the mapping of strategies used in the production control. Therefore, Rooks (2009) deals with the issue that automatic generated models can hardly simulate complex system behavior. His approach is to replace missing specification of the planner, by an expert. Selke (2004) gives another approach to deal with the complicacy. He identifies strategies by analyzing the status data of the real system. Herby he regards production control strategies and decisions taken by humans. An intervention of planners is not needed. Therefore the acceptance is dubious.

Mutability is a factor of success for manufacturing companies. There is a need to establish reaction scenarios on market changes (Wiendahl 2009). Therefore it is crucial to use planning instruments for adaptive systems, such as modular simulation models. Wenzel (2011) illustrates how to construct and to realize the modular design of simulation models. The standardization of custom designed components and the modularization are instruments to improve model-based planning. Flexible factories involve new challenges for construction and usage of simulation models with re-usable modules for different branches. Wenzel (2011) defines a module as a combination of individual components such as workplaces, buffers or lists. The modules used are adapted towards the present problem.

Nevertheless, all presented approaches of proper simulation generation require high expert knowledge in order to develop simulation models reflecting the reality exactly. Another challenge is to achieve acceptance of the simulation model amongst all participating operators.

3 CHALLENGES OF PRODUCTION CONTROL

In recent years, delivery times reduced dramatically, in some branches up to 50 %. This has changed the order situation and increased the demand for flexible capacities (Wiendahl 2005). In order to achieve the necessary decrease in throughput times, an adequate design of production control is required. The optimization process is based on employee's knowledge on the one hand and adequate software support on the other hand.

Within the following paragraphs the paper will take a closer look on some of the challenges the production control has to deal with.

3.1 Internal Influences on Production Control

The dynamic in the production has internal influencing factors. Following Schuh (2011) several internal influencing factors are for example

- changes of sequences,
- premature order release and capacity overload,
- other short-termed control interventions, and
- nontransparent control strategies in the IT systems.

Especially in companies aiming at high customer satisfaction through high flexibility and customizability it can be observed that the production flow is interrupted very often by rush orders as well as many changes of production sequences. This behavior leads to increasing throughput times for all other orders. Consequently a rising number of rush orders has to be created leading again to more interruptions. Another measure is premature order release bringing about capacity overload. An increasing work in process enlarges waiting lines and the scattering of throughput times. These kinds of short-term control interventions reinforce the internal dynamic and therefore have a negative impact on the predictability of the production output. As a result, the optimizing of single orders leads to a reduction of the overall performance of production (Nyhuis 2008).

Furthermore there is a lack of easy visualization and analysis of these correlations.

3.2 Process Understanding of Employees

Another challenge is to increase transparency of the installed control logic and to extend operators' understanding why solutions have been installed. Since the options of different configurations of production control are immense, a number of predictable, irrational decisions are made (Schuh 2011). These decisions lead to a poor performance in fulfilling the logistic targets in production because they are often counterproductive to the tasks already fulfilled by the control logic. For example within multiple-machine operation, the workers decide about the short term sequence in the context of disturbances like missing parts or other statistical parameters. Since operators do not have the essential process understanding and context information, irrational decisions are made. Decisions which require a certain context cannot be made by some superior planning division. They have to be made in a decentralized manner, close to the process where the context is still available to the decision maker. By reason of missing information and transparency as well as a deficient ability to evaluate the scope of decisions, a systematic support of decentralized decision making process does not take place sufficiently today (Schuh 2009).

3.3 Wrong Configuration of Production Control

Today there is a wide range of production control concepts. The experiences in the industry show that different strategies are applied, without knowing their characteristics and their interaction (Schuh 2010a). Therefore it is very difficult to find the right configuration of the optimal production control.

The constant development of new methods of production control like Manufacturing Resource Planning (MRP), Kanban or CONWIP offered new possibilities on the one hand but led to a selection problem on the other (Gaury 2000). With an increasing number of alternatives of different methods, the advantages of a high availability of alternatives turns into a burden (Lödding 2003). The high complexity of the decision process makes it very often ineffective (Schwartz 2005).

In addition to the problem mentioned above, wrong configuration of production control can also occur due to the so called polylemma of production planning (Muenzberg 2009). The polylemma of the production planning describes a conflict between four competing goals. These competing goals are the following:

- Minimization of the throughput times,

- Minimization of the work in process,
- Minimization of exceeding of delivery dates,
- Maximization of capacity utilization.

It is not possible to optimize all of the conflictive logistic targets at once. E.g. in order to maximize the capacity utilization, orders are grouped to save on setup times. But this inevitably leads to longer throughput times because other orders are put in a queue in front of the machines (Baye 2009).

In order to demonstrate how to deal with the challenges of production control in an efficient way by using simulation models, the web-based simulation model approach is presented in the following chapter.

4 APPRAOCH OF WEB-BASED SIMULATION MODEL

The concept of the value stream oriented production control is based upon the ideas of the research project DIGIPRO (digital value stream design; research project of the University of Applied Science and of the Technical University Braunschweig in collaboration with Siemens PLM Solutions GmbH). The main focus of DIGIPRO lies on the interconnection of the value stream design and the approach of the digital factory (Brüggemann 2008). Beyond that, Schuh's concept of the value stream oriented production control integrates the logic of the production control by Lödding (Schuh 2010a, Lödding 2010). In contrast to most other approaches which mainly consist of control strategies for job release and sequencing at machines, the concept of value stream oriented production control also includes order creation. (Lödding 2008) According to the categorization in chapter 2 it can be seen as a hybrid approach.

The basic framework for the configuration of production control is a three layer model that starts with the value stream on the shop floor (see Figure 1). The value stream represents the production process. The intention is to display segments of equal production control configuration along the production process. The production control layer describes the configuration of the production control and the information needed both from the master data, order data and from the shop floor. Manufacturing master data and order data are the input for all planning and control activities. They consist of work plans, bill of material and customer demands represented in a master production schedule. The third layer allows the link between changes of the configuration of production control or on the shop floor and changes within master data, as data inconsistencies are often the origin of many problems in production control (Schuh 2010b). To solve the problem of inconsistent master data a periodic feedback e.g. of the actual process time is implemented between the third and the second layer.

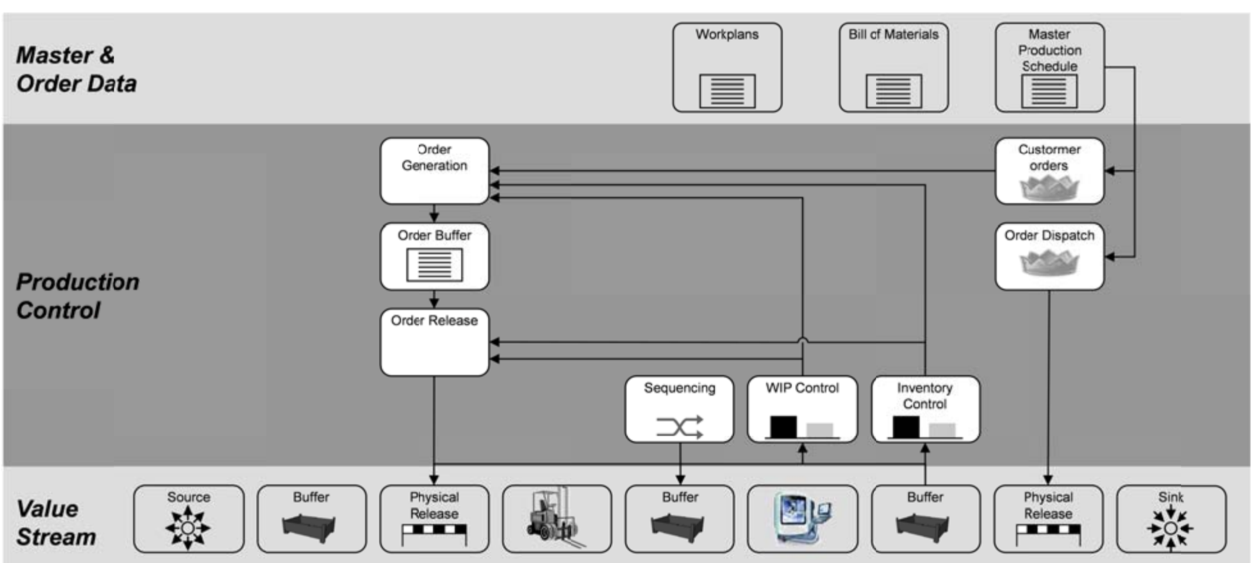

Figure 1: The three layers model of production control

Only by including all parameters of the production control, it is possible to find a customized and optimized configuration for a company. That is the reason why the value stream oriented production control approach determines the influence of the configuration of the production control on logistic performance factors (inventory, delivery accuracy, throughput time, capacity utilization) as a whole.

The simulation tool which supports the configuration process is called PlantSimulation by Siemens. In the beginning, a simulation toolkit was developed which consisted not only of resources like machines, inventories etc. but also of controlling devices like Kanban, CONWIP or MRP.

According to Lödding (2008) this includes job creation, job release, sequencing and operational capacity control. Only by integrating the control in the aggregated production system it is possible to find an optimized and customized configuration for the company.

Possible control strategies are ASAP (immediate release), Kanban and MRP. ASAP, CONWIP, various load-dependent order release principles and MRP-dates are possible job release strategies. For sequencing in front of each machine one can choose between the strategies First in first out (FIFO), slack, shortest operating time (SOT), longest operating time (LOT), set-up time optimization and earliest date required (Schuh 2006).

Since today's simulations are only accomplishable by experts, the web-framework is developed to enable also non-simulators (non or semi-professionals) to evaluate their factory control and to optimize it.

4.1 Web-interface for Operators

The main advantage of this approach is the user-friendly interface. The main structure of the user interface consists of a field for input data, a field for the configuration of production control and a field for the results of the simulation (see Figure 2).

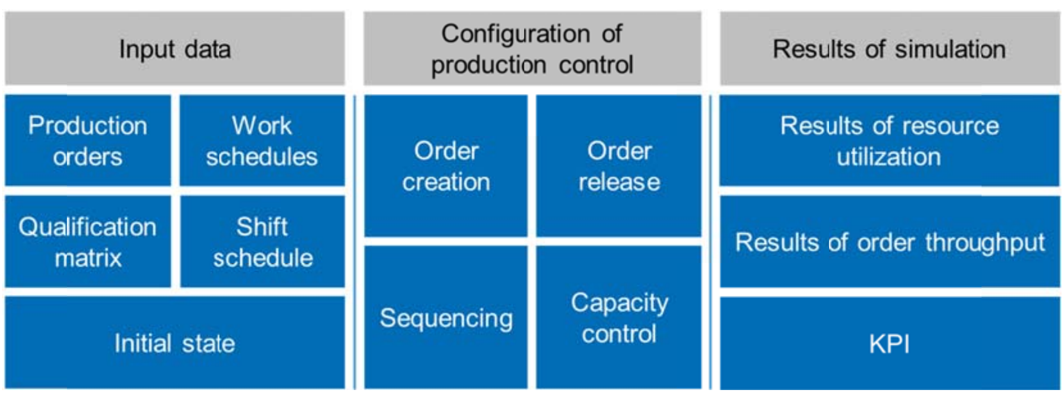

Figure 2: Mock-up of web-interface of simulation

The input data generally consists of work schedules and production orders, provided by Enterprise Resource Planning-system (ERP). This data is necessary to generate resources and orders within the simulation model. Furthermore the availability of employees has to be recorded by the shift schedule and the qualification matrix. This is also important to ensure flexible employment in case operators get sick etc.. The input data of the availability of employees is entered in an adjusted way, which means that experienced data (e.g. of the status of employee's illness) is already included. Finally the simulation needs an initial state to start with. Since production data from ERP-systems always begins at a certain date when some orders have already started, the initial state can be derived from the feedback data from production.

The configuration of the control strategies is following right after the specification of input data. The four task of production control can be selected. Then, the control strategies of each control task can be allocated to the machines. Even for these steps, there is no simulation knowledge needed. The operator just interacts with the web-based user interface. The generation of the simulation modules is done in the background of the system, where the input data is being parameterized and simulation modules are generated.

After having configured the control strategies, the user activates the simulation. This also takes place in the background with the aid of PlantSimulation (Siemens). After the simulation is finished, the system displays various results like the resource utilization and the throughput of orders etc.. The results are also presented on web-surface which enables the user to interactively analyze the results.

4.2 Upload of Input Data and Configuration of Production Control

The upload is made via a web-based platform. Thereby, the employee does not directly get in touch with the simulation. In figure 3 the mask to upload the production orders is displayed. The employee uses the "Browse" button to find the production orders stored from the ERP-system. To get a style sheet a csv-file can be downloaded via the "Download csv" button. In the same way, all other input documents can be uploaded.

Figure 3: Mask to upload input data

After uploading all input data, the configuration of production control is necessary. In Figure 4, the configuration of sequence is presented exemplary. The figure shows all machines on the right side, which are registered within the uploaded work schedules. Now, the user can determine the sequencing to be used at each machine. Therefore, he can chose between the described strategies FIFO, SOT, LOT LIFO and set-up time optimization. The colored visualization helps user to check whether all machines are configured. The manual selection is obligatory for every resource. By using the button "All resources" on the left side, all resources can be selected at once. This is useful in case that all resources have same prioritization.

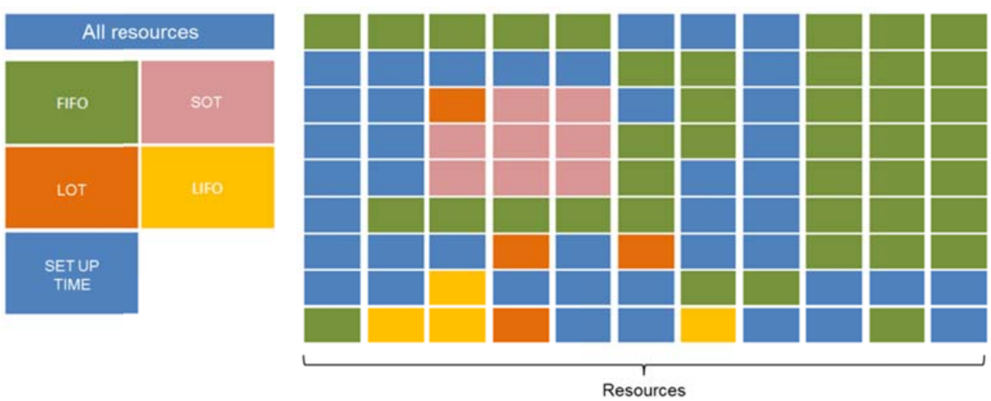

Figure 4: Configuration of sequence per resource

After uploading the input data and configuring the production control, the simulation starts. The results of the simulation are displayed afterwards on the web-surface in the according fields. Currently the simulation is conducted successfully with a data set of more than 200 machines and 200.000 processes, with a computing time of less than five minutes. The level of detail of the simulation is medium, which means that there are no rules for specific companies included. Those internal rules (e.g. automatic transport systems between machines) can be implemented if demanded by a certain customer.

5 CONCLUSION AND OUTLOOK

The presented approach describes simulation model generation by using operating data of real production systems. By using this model, no simulation expert knowledge is required. The advantage of this web-based value stream oriented simulation model is it's modular structure and it's simple adaptability. Furthermore, the user is supported within his decision making process by easy to understandable web-surface. By integration of employees within the simulation generation process, the acceptance in simulation and in simulation results increases.

The next step is to validate the generated model automatically. Therefore, results of simulation are compared with real production data. In case of bigger deviation, the simulation model will be adapted. After validation of the simulation model, optimizations of the production control can be made by exchanging the described control modules for job creation, job release, sequencing and operational capacity control. The user will be able to automatically receive the optimized controlling and sequencing parameters as well as their optimization potential. This will be done with the help of genetic algorithms. Therefore, the user has to describe its optimization goal like e.g. delivery accuracy or throughput time.

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