Virtual Production Intelligence – A contribution to the Digital Factory

Rudolf Reinhard, Christian Büscher, Tobias Meisen, Daniel Schilberg, Sabina Jeschke

Institute of Information Management in Mechanical Engineering (IMA)
RWTH Aachen University, IMA der RWTH Aachen, Dennewartstr. 27,
D-52068 Aachen, Germany
{rudolf.reinhard, christian.buescher, tobias.meisen, daniel.schilberg, sabina.jeschke}@ima-zlw-ifu.rwth-aachen.de

Abstract. The usage of simulation applications for the planning and the designing of processes in many fields of production technology facilitated the formation of large data pools. With the help of these data pools, the simulated processes can be analyzed with regard to different objective criteria. The considered use cases have their origin in questions arising in various fields of production technology, e.g. manufacturing procedures to the logistics of production plants.

The deployed simulation applications commonly focus on the object of investigation. However, simulating and analyzing a process necessitates the usage of various applications, which requires the interchange of data between these applications. The problem of data interchange can be solved by using either a uniform data format or an integration system. Both of these approaches have in common that they store the data, which are interchanged between the deployed applications. The data's storage is necessary with regard to their analysis, which, in turn, is required to obtain an added value of the interchange of data between various applications that is e.g. the determining of optimization potentials. The examination of material flows within a production plant might serve as an example of analyzing gathered data from an appropriate simulated process to determine, for instance, bottle necks in these material flows.

The efforts undertaken to support such analysis tools for simulated processes within the field of production engineering are still at the initial stage. A new and contrasting way of implementing the analyses aforementioned consists in focusing on concepts and methods belonging to the subject area of Business Intelligence, which address the gathering of information taken from company processes in order to gain knowledge about these.

This paper focusses on the approach mentioned above. With the help of a concrete use case taken from the field of factory planning, requirements on a data-based support for the analysis of the considered planning process are formulated. In a further step, a design for the realization of these requirements is presented. Furthermore, expected challenges are pointed out and discussed.

Keywords: Application Integration, Data Analysis, Decision Support, Digital Factory

1 Introduction

Due to the global price competition, the increasing ranges of varieties and customer requirements as well as resulting shorter product lifecycles, production companies in high wage countries face a growing complexity within their production circumstances (Schuh et al. 2011 A). Methods and concepts which are used in order to overcome this complexity often fail to address the whole production process. Therefore, solutions are needed, which allow a holistic and integrated view of the relevant processes in order to achieve an increasing product quality, production efficiency and production performance (Brecher et al. 2011).

Within the last years, the usage of simulation applications in the field of production technology became a measure with a growing significance to overcome the complexity mentioned above. Because of the increasing computing performance concerning speed and storage, these simulation applications changed the way of carrying out planning and preparing activities within production. So, instead of engineering a concrete prototype at an early stage of product design, a digital model of this prototype is drafted containing a description of its essential characteristics. In a further step, this model is passed to a simulation application to predict the prototype's characteristics that may have changed after having passed the manufacturing step. The usage of these digital models is subsumed under the notion of virtual production, which "is the simulated networked planning and control of production processes with the aid of digital models. It serves to optimize production systems and allows a flexible adaptation of the process design prior to prototype realization." (VDI 2008), (VDI 2011)

Nowadays, various simulation applications exist within the field of virtual production, which allow for the simulated execution of manufacturing processes like heating and rolling. Herein, different file formats and file structures were independently developed to describe digital models. Through this, the simulation of single aspects of production can be examined more easily. Nevertheless, the integrative simulation of complex production processes cannot be executed without large costs and time efforts as the interoperability between heterogeneous simulation applications is commonly not given.

One approach to overcome this challenge is the creation of a new standardized file format, which supports the representation of all considered digital models. However, regarding the variety of possible processes, such an approach results in the creation of a complex, standardized file format. Its comprehension, maintenance and usage, again, require large costs and time efforts. Furthermore, necessary adaptations and extensions take a lot of time until their implementation is finished (Nagl et al. 2003), (Horstmann 2011).

Another approach considers the usage of concepts from data and application integration avoiding the definition of a uniform standard. Within this approach, the interoperability between the simulation applications is guaranteed by mapping the aspects of different data formats and structures onto a so called canonical data model (Steve 2008) , (Schilberg 2010). Newer approaches extend these concepts with regard to semantic technologies by implementing intelligent behavior into such an integrative system. This approach is called Adaptive Application and Data Integration (Meisen et al. 2011), (Reinhard et al. 2012).

As a consequence, new possibilities concerning the simulation of whole production processes emerge, which allow the examination of different characteristics of the simulated process, e.g. material or machine behavior. With regard to the analysis of the integrated processes, new questions arise as methods for the analysis of the material or machine behavior mentioned above cannot be transferred to the analysis of the corresponding integrated process. A further challenge comes up as soon as suitable user interfaces are added, which are necessary for the handling of the integrated process and its traceability.

Similar questions emerge whilst the analysis of enterprise data. Applications giving answer to such questions are subsumed under the notion of Business Intelligence. These applications have in common that they identify, aggregate, extract and analyze data within enterprise applications (Byrne et al. 2008), (West 2011).

In this paper, an integrative concept is introduced that transfers the nature of these solutions to the field of application of production engineering. It contains the integration, the analysis and the visualization of data, which have been aggregated along simulated process chains within production engineering. In respect to the concept's application domain and its aim to contribute to the gaining of knowledge about the examined processes, it is called Virtual Production Intelligence. In order to illustrate this approach, in chapter 2, a use case scenario from factory planning is taken into consideration. In chapter 3, requirements are listed, which arise from the use case scenario described in chapter 2. The realization of these requirements makes it necessary to create new concepts, which are presented in chapter 4. Chapter 5 contains a description of expected challenges that come up while realizing the requirements defined in chapter 3. This paper concludes with a summary and an outlook on a further use case.

2 Use Case Factory Planning

The notion of virtual production comprises the planning of processes that are characteristic for factory planning. In this chapter, a scenario taken from the field of factory planning is introduced, which follows the concept of Condition Based Factory Planning (CBFP). This concept facilitates an efficient planning process without restricting its flexibility by making use of standardized planning modules (Schuh et al. 2011 B). With the help of this scenario, it is pointed out which data are aggregated and which questions are raised concerning the integration, analysis and visualization of data within the planning process of a factory aiming at the support of this planning process. In the following, after having illustrated the use case, the examination of the planning process aforementioned is subsumed under the notion of Virtual Production Intelligence.

The concept of CBFP is employed to analyze factory planning scenarios with the aim of facilitating the factory planning process by decomposing it into single modules (Schuh et al. 2011 B). These modules address various aspects within factory layouting

like material flow or logistics. Because of the modular procedure, the characteristical non-linearity of planning processes can be mapped onto each process' modeling.
Within various workshops, requirements concerning the future factory are gathered in collaboration with the customer. For this purpose, table calculation and simulation applications are employed. Subsequent to these workshops, the gathered data are evaluated by one of the factory planners, who participated in the workshops, and suitable planning modules belonging to CBFP are identified. Thereby, different scenarios of the factory's workload are examined to guarantee the future factory's flexibility. Figure 1 illustrates this procedure focusing on the exemplary planning modules Product Planning, Process Planning, Capacity Planning, Planning of Floor Space Requirements, Logistics and Stock Design as well as Production Control.

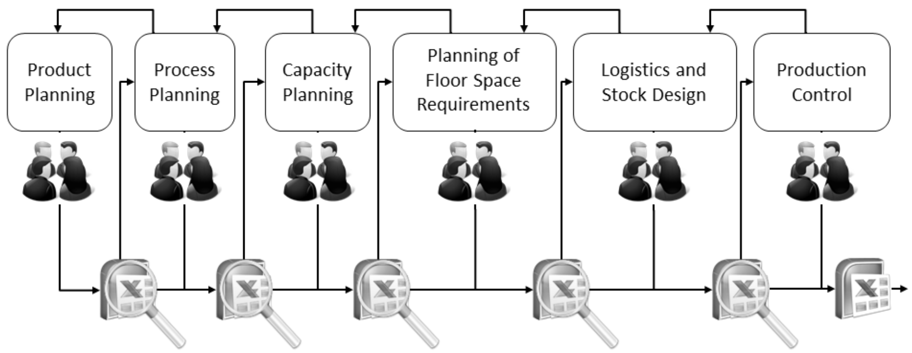

Figure 1 - Exemplary non-linear factory planning process following CBFP

Although the planning process is supported by the planning modules from CBFP, a significant disadvantage remains as the procedure is vulnerable concerning input errors committed by the user. Furthermore, the automated analysis of gathered data is complicated, due to the lack of a uniform data model.

The support of the planning process is based on a data model, which fulfills the planning modules' requirements. Thereby, the collection of data is performed by making use of familiar applications. Each analytical step, e.g. the calculation of different scenarios of the factory's workload, is computed on a dedicated server by the factory planer during the evaluation phase between two workshops. One advantage of this procedure is the coherent data handling during the entire planning process. Because of this coherent data handling, the design output can be made available for uninvolved and, in particular, new employees as well as for the executives after having finished a planning process. An interactive visualization allows for an explorative analysis of the simulation application's output. Such an integrative solution facilitates the location of possibilities for optimization within the examined processes. As an organizational consequence and a lasting effect, the experiences made during the implementation of optimization processes can be employed with regard to the composition of best practices for planning projects within the planning company. The implementation of the integrated solution is depicted in Figure 2.

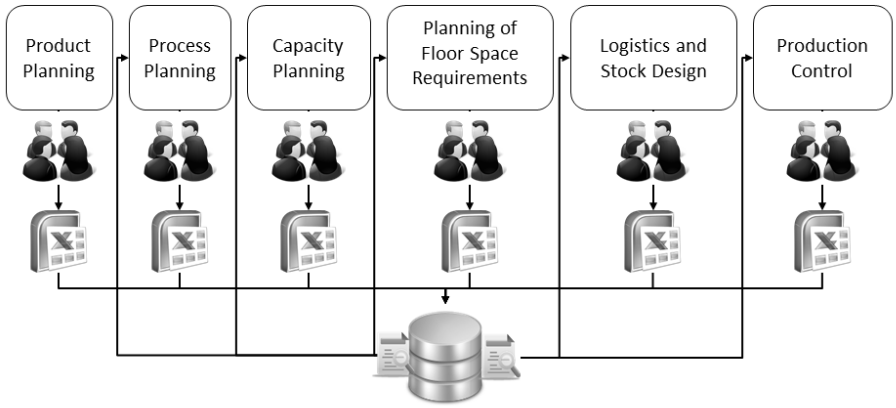

Figure 2 - Exemplary Factory Planning Process following CBFP, supported by an integrative solution

As a consequence of the integrated consideration, different fields of employment emerge, for instance the immersive visualization of a digital model of the future factory within a Cave Automatic Virtual Environment (CAVE). This immersive visualization provides the possibility of inspecting the future factory virtually. In doing so, the customer gets the option to feedback the current state of the factory's planning process, which in turn leads to an improved satisfaction regarding the planning's outcome. The creation of the interoperability between the involved applications, on the one hand, and the integrative data handling and analysis, on the other hand, results in the provision of such a solution without generating larger costs and time efforts.

Furthermore, the usage of this solution allows for the examination of different outcomes within a planning problem, e.g. the distribution of machines within a hall and the corresponding planning aspects like logistics or staff security, on a homogeneous data basis. Such a solution might also be adapted to the requirements of another field of application, like marketing, if the attention is directed to the presentation of the planned area rather than to the computing accuracy. Another field of application is the training effort for new employees. Its reduction is an important aim due to high wage costs. In this context, different views adapted to relevant questions of new employees can be used, which comprise the complete and detailed presentation of the current project as well as of past projects.

The scenario described above, which includes methods from factory planning, illustrates how the support of the planning process can be designed. In this scenario, the integration, the analysis and the visualization of data gathered during the planning process is realized. The following chapter comprises a description of requirements that need to be fulfilled when dealing with a system that provides the aforementioned support of the planning process.

3 Requirements on an integrative solution based on an analysis for process data

The virtual production aims at an entire mapping of the product as well as of the production within a model for experimental purposes. Thereby, the mapping should comprise the whole lifecycle of the product and of the production system (Bracht et al. 2011). Within an enterprise, the virtual production is established by employees, software tools such as Product-Lifecycle-Management applications (PLM applications) and organizational processes (Bracht et al. 2011).

The demanded possibilities for analysis serve the purpose of gaining knowledge by examining already completed planning processes. The term “intelligence” is commonly used to describe activities that are linked to those analyses. Software tools, which support the analysis and the interpretation of business data, are subsumed under the term “Business Intelligence”.

As this term can be defined in different ways, at this point, the basic idea of “Business Intelligence” will be pointed out (Luhn 1958), (Kemper et al. 2006), (Hummeltenberg 2009). A common feature of the definitions referred to consists in the aggregation of relevant data from different data sources, which are applications within a company, into a central data storage. The transmission of data taken from the application data bases into this central data storage is realized by the well-known Extracting, Transforming and Loading process (ETL). Subsequently, the data are arranged in more dimensional data cubes following a logical order. In doing so, a company’s IT is divided into two different categories:

- Operational: This category contains applications customized for e.g. the accounting department, the purchasing department or the production department of a company.
- Analytical: In this case, the category contains applications for the analysis of data arising from the applications mentioned in the operational category.

The fact that operational processes are not influenced by analytical processes can be regarded as an advantage of this division.

Requirements for a system that supports the described planning process in chapter 2, in particular the data and application integration, and which additionally follows the idea of Business Intelligence can be subsumed as below:

- Interoperability: Facilitating the interoperability between applications in use.
- Analytical abilities: Systematic analyses providing the recognition of potentials towards optimization and delivering fundamental facts for decision support.
- Alternative representation models: Taylor made visualization for the addressed target group, which provides appropriate analysis facilities based on a uniform data model.

In order to find a solution, which fulfills the requirements mentioned above, a concept formation is needed that addresses the field of application, that is, in this case, the virtual production already mentioned above, as well as the aim of gaining knowledge. This aim is also addressed by the term “Intelligence”. The concept formation will take into account approaches, methods and concepts. These will contribute to the achievement of objectives concerning the gaining of knowledge with regard to the processes executed within the considered field of application, which is the virtual production. Therefore the concept formation results in the notion of Virtual Production Intelligence.

This notion will be described in the following chapter.

4 Objectives of the Virtual Production Intelligence

The Virtual Production Intelligence (VPI) is a holistic, integrated concept that is used for the collaborative planning of core processes in the fields of technology (material/machines), product, factory and production planning as well as for the monitoring and control of production and product development:

- Holistic: Addressing all of the product development's sub processes.
- Integrated: Supporting the usage and the combination of already existent approaches instead of creating new and further standards.
- Collaborative: Considering roles, which are part of the planning process, as well as their communication and delivery processes.

The VPI aims at contributing to the realization of the digital factory, which is defined as follows:

Digital factory is the generic term for a comprehensive network of digital models, methods and tools – including simulation and 3D visualization – integrated by a continuous data management system. Its aim is the holistic planning, evaluation and ongoing improvement of all the main structures, processes and resources of the real factory in conjunction with the product (VDI 2011).

The concept is evaluated by the technical implementation of a web-platform, which will serve as a support tool. This platform will serve for planning and support concerns by providing an integrated and explorative analysis in various fields of application. Figure 3 illustrates how the platform is used in these fields of application by various user groups. Within the figure, the use case "factory planning" is addressed as well other use cases, which will be described in future publications.

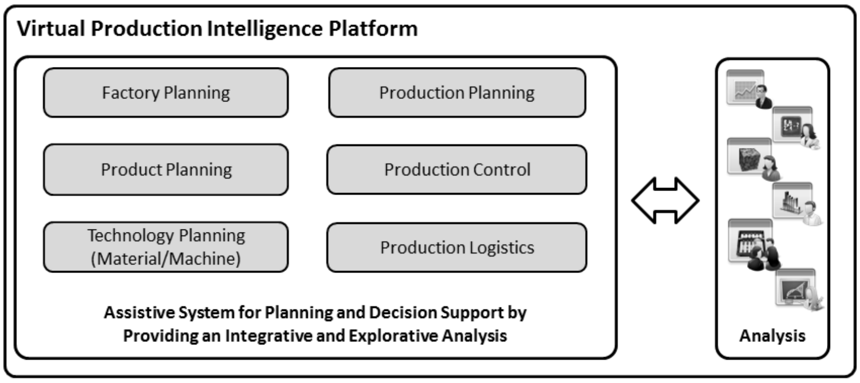

Figure 3 - The concept of the Virtual Production Intelligence' Platform

5 Challenges

The integrative approach of the VPI concept facilitates the use of various applications, which can, for example, be deployed whilst a planning process without requiring a uniform data format. At the beginning of the use case scenario already described above, different utilization rates of factory capacity are defined. As a consequence, further requirements arise, which concern, for example, the future factory's layout, logistics or stocks. Within the planning process of the factory, data are generated on a large extent. The use of these data depends on the future utilization rates of the factory capacity. In order to analyze the planned processes of the future factory, it is provided that these processes are evaluated beforehand. The planning of these processes will only create an additional value if the identified potentials for optimization are considered in the real process.

Comprehensively, the following questions have to be answered from a planner's point of view:

- Which of the data generated during the process planning are relevant?
- Which key performance indicators are needed with regard to the validation of the considered processes?
- How can the gained knowledge be fed back into the real process?

Regarding the field of information technology, the following questions arise:

- Which data model facilitates the data's analysis?
- Which data analysis methods known from Business Intelligence can serve as role models?
- How to validate the data model's and analysis' functionality appropriately?

Topics that were not considered above will be addressed by the following questions:

- Which simulation model for the considered process is preferred by the user?
- How can the process in consideration be decomposed?
- Which added value may the user expect?

In retrospect, these questions address technical, professional as well as organizational aspects.

6 Summary and outlook

Within this paper, a concept named “Virtual Production Intelligence” (VPI) has been presented, which describes how the solutions developed within the field of “Business Intelligence” can be adapted properly to the one of virtual production. This concept, which is both holistic and integrated, is used for the collaborative planning, monitoring and control of core processes within production and product development in various fields of application.

Furthermore, the technical implementation of this concept was made a subject of discussion in terms of the Virtual Production Intelligence Platform (VPI-Platform). The platform’s implementation is particularly based on concepts and methods established in the field of Cloud Computing. Challenges that might occur during the realization of the platform were taken into account with regard to technical, professional and organizational aspects.

A further scenario, which will point out the VPI's flexibility, will be taken from the field of laser cutting. Thereby, the focus will lie on the problem of analyzing a simulated cutting process in such a way that desired characteristics of the concrete cutting process can be realized. The configuration settings for the cutting machine resulting in the desired cutting quality are a part of the analysis outcome. An additional value for the real cutting process arises after feeding back the analysis outcomes into this process.

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