Integration of manufacturing operations management tools and discrete event simulation

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Abstract. The growing popularity of IT tools and interest in the use of modelling and simulation tools in the era of modern manufacturing concepts development, such as the industry 4.0 implies increasing use of computer applications in management and manufacturing. In the problem addressed in this paper, an operation management tools and DES systems integration based on data-driven semi-automatic simulation models generation method is presented. The presented approach allows the use of simulation and visualization for rapid verification of production flow plans. The concept of semi-automated model generator based on data-driven is applied. The approach has been illustrated through examples of practical implementation of the proposed method using FlexSim simulation software.

1. Introduction

The rapid growth of information systems and networks, development of modern production planning and control methods as well as development of modern manufacturing concepts, such as the industry 4.0 implies increasing use of computer applications in business and manufacturing systems. It enables easier changes to production plans and delivers the ability to flexibly respond to customer requirements. Industry 4.0 is focused on creating smart products, procedures and processes and on the aspect, i.e., digital integration of engineering and networked manufacturing systems. Process engineers should be equipped with the IT tools and methods required to develop a complex planning and explanatory models. In this context, the modelling plays a key role in managing the increasing complexity of production systems [1, 2, 3, 4, 5]. To meet these requirements, entrepreneurs are increasingly implement extensive software platform to support many aspects of manufacturing operations management, including enterprise resource planning (ERP), Advanced planning and scheduling (APS), product lifecycle management (PLM), and manufacturing execution system (MES). On the other hand, the dynamics of changes concerning new technologies, their frequency, creates difficulties in introducing changes in enterprises, due to the very small margin of error and the potential costs of failure. Therefore, the increased interest in the use of modelling and simulation tools is observed and the methods of integration planning and simulation system are sought [6, 7]. This allows a significant increase in the level of confidence in operational decisions process that is very important for manufacturers. Discrete Event Simulation (DES) is therefore an important tool in the development and improvement of. In the problem addressed in this paper, an operation management
tools and DES systems integration based on data-driven semi-automatic simulation models generation method is presented. The proposed approach allow to eliminate the time-consuming process of creating the simulation models [7, 8, 9]. There are a series of processes that should be adhered to in order to build a simulation model that meets the requirements. The key role within simulation has a data collection process, as the data must the data must reflect the state of the production system and the production orders planned for execution. The novelty of the proposed solution is that the external data sources not only are linked to the model data in order to enable automated updates, but on the basis of the external data, the entire simulation model is created in semi-automatic way. The proposed RapidSim software solution enables rapid analysis of production plans with regard to the available quantity and capacity of resources and may be commercialized with any operations management software tools. Presented in this paper data collection method is based on parametric hybrid approach, combining the method of data mapping and data transformation.

The article presents the original method of integration of ERP systems with simulation systems. Section 2 presents a brief description of simulation systems in supporting production planning. Section 3 presents integration of manufacturing operations management and discrete event simulation systems with an example of a practical realization of this concept. Finally, Section 4 concludes the research with a propositions of directions for future work.

2. Simulation systems in supporting production planning

Currently used methods and modelling tools are still based on manual data entry and analysis of results. This causes that the use of these methods is very difficult, especially in the context of the needs of modelling and simulation of increasingly larger and more complex systems, which is one of the main challenges in this area [6, 10, 11]. The answer to these needs is research on the methods of semi-automatic and automatic generation of simulation models [10, 11]. They are based on the concepts of creating simulation models from external data sources using data exchange interfaces with simulation systems or modelling algorithms. Therefore, the simulation model is not created in a standard way, using functions or visual simulation tools. The previously developed semi-automatic methods of generating models can be divided into three main categories [12, 13, 14]:

- structural approach: generation of models is based on data describing the structure of the production system (usually in the form of data on the location of equipment on the production floor),
- parametric approach: models are generated based on existing building blocks (atoms) stored in libraries, selected and configured on the basis of parameters from other systems,
- hybrid approach: combining AI methods (expert systems, neural networks, etc.) with the two presented above.

Most of the concepts of generating simulation models presented in the literature can be implemented only with dedicated computer simulation systems or they enable generation of simulation models for a specific structure of the flow of production processes. This makes it difficult to use them widely in industrial practice, mainly due to the inability to quickly adapt the model to the new configuration of the production system. Many of them are still in the conceptual phase or their practical applications are lacking. The research gap mentioned was the main motivating factor for the development of the author's semi-automatic method of generating simulation models based on a parametric approach. The approach proposed in this paper constitutes a development of the above-mentioned concepts that could be implemented in any commercial simulation systems with 3D visualization of processes flow in the system.

The most popular systems currently supporting enterprise resource planning, integrating different areas and levels of management, are ERP class systems that have a decisive influence on the company's production and business operations [16]. In the area of organizational production preparation, MRP I, MRP II modules or dedicated modules supporting the scheduling process are particularly used. Unfortunately, in most cases, the modules used to support production flow planning processes do not take into account all organizational constraints, including constraints related to the areas of the production system, storage and internal logistics. In order to fully verify the received
production plans, especially in terms of "ergonomics" of the manufacturing system (detection of possible collision threats, location and available storage capacities) and their impact on the ability to meet the planned production standards - it is necessary to search and implement advanced planning tools in planning processes computer support.

3. Integration of manufacturing operations management and discrete event simulation systems
The aim of the research is to develop an efficient and effective method of integrating ERP systems with simulation systems, which is also a method of semi-automatic generation of models for simulation systems. Its accomplishment will contribute to eliminating the above problems and enabling a wider use of simulation systems in supporting the verification of production flow. Methods of integrating ERP systems with external modules or dedicated systems, based on data exchange interfaces, are currently used to extend the functionality, efficiency and effectiveness of the organization's activities in various functional areas. The method proposed in this paper uses the Extensible Markup Language and is based on mapping techniques as well as data transformation - it is an extension of the traditional approach based on data exchange interfaces with functions generating program code to the target system at the data exchange stage. This data is obtained from MRP I / II or ERP systems for the purpose of semi-automatically generating scripts for simulation systems. The quality of generated models is verified, among others regarding the criteria, completeness of production, auxiliary and information resources, resource parameters or dispatching rules.

3.1. Semi-automatic generation of models for simulation systems
The achievement of the set goal will be implemented in four basic stages. The first stage is related to obtaining complete data required to prepare a functional simulation model. Data representation methods are used using the extensible XML markup language (which is a neutral data storage format) and data mapping and transformation methods. These data are obtained from IT systems supporting business management at various levels and functional areas (ERP, MRP, PPC, APS, etc.). Examples of PPC/ERP class modules that allow to obtain data in the form of XML documents are: NetWare of the SAP system or IFS Connect of the IFS Applications system.

In the next stage, data exchange processes are carried out between the source data representation and the neutral intermediate data model. They include both the data required in the next stage to generate components of the simulation model, describing the resources of the production system, the production order, as well as procedures for controlling the work of resources (production plans). In the
next stage, data from the intermediate model are transformed directly into the program code created in internal programming languages of simulation systems. The last stage is adding model-specific objects to the model and parameterized information about procedures controlling the flow of processes on the resources (carried out by the system operator) in order to conduct simulation experiments (figure 1).

The automatic generation of code in the internal programming language of the simulation system, containing instructions for creating a complete simulation model, is carried out using the automated programming methods. As input in the process are used only instance of an intermediate neutral data model [7].

The above mentioned method and developed definitions of output data structure from ERP systems and data transformation were implemented in RapidSim software [7, 4] (figure 2). The software includes the following modules:

- graphical user interface,
- validation and parsing module for XML documents,
- XSLT processor,
- script generator of the simulation model,
- module for creating and editing XML and XSLT documents,

The software is a universal tool and can be commercialized with any planning system in any production company.

![Figure 2. RapidSim model generator.](image)

### 3.2. Model generation

The practical implementation of the presented method was carried out using a commercial ERP - IFS Applications system and the FlexSim simulation system.

IFS Application system is a complete ERP class system solution and is an integrated product, supporting the main areas of business management: Manufacturing, Service and Asset, Projects and Supply Chain. IFS Manufacturing supports planning, control, execution and analysis in many types of manufacturing (Repetitive, Batch Manufacturing, Make to Stock, Configure to order, Make to order, Engineer to order), from mass production of high-volume products to mass customization and several different production models in all manufacturing process phases. IFS Manufacturing handles various EDI standards, including EDIFACT and ANSI X12 as well as XML messages. IFS Component Architecture is an open architecture, and the integration process with other application is provided through IFS Web Services or the IFS Connect integration broker. [7, 17].
For production orders, batch material lists and routes are assigned that generate real demand and loads. Data on production plans prepared in the ERP system along with other data on, among others, production system resources were used as source data for the simulation model generator for the FlexSim simulation software (figure 3).

Then, calculations were performed and an XML document was generated. It contains data on production resources, warehouses, data on production processes and rules controlling the work of resources. The generated XML document was loaded in the RapidSim integration software and (for prepared batch files of transformations and data mapping) an input file was generated for the FlexSim simulation system, containing a complete simulation model, including data on the production system and the flow of production orders (figure 4). Due to the fact that in the ERP system (being the source of data used in the presented method), usually the parameters of internal transport (speed, acceleration, capacitance, etc.) are not known, objects that map the behaviour of the transport and manipulation system are generated with default parameters that can be easily changed (updated) by the planner before performing simulation verification experiment.

Figure 3. Entering data into the IFS system.

Figure 4. RapidSim software.
The simulation model code contains pre-parameterized basic objects. Figure 5 shows the complete simulation model created after loading into the FlexSim software.

![Figure 5. Simulation model in FlexSim.](image)

The presented example of creating a simulation model exposes the usefulness of the proposed solution in supporting the process of verification of production flow plans. In addition, it can be a valuable tool to optimize the parameters of the production system, depending on the adopted criteria for assessing the solutions sought.

4. Conclusions
The method of integration of planning systems with discrete simulation systems presented in the paper, which is also a method of semi-automatic generation of simulation models, enables quick creation and easy modification and parameterization of the models. It can become an efficient and effective tool supporting the process of planning and verification of production flow, taking into account production constraints. The developed RapidSim software has confirmed its usefulness as a universal integrating module. The results of the experiments shown also indicate the usefulness of the presented concept of using simulation as a tool supporting production management processes.

The subject of further work in the discussed area will be related to the expansion of indirect data models with information that can be obtained in ERP systems regarding other subsystems and limitations of production systems.

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