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Integration of scheduling and discrete event simulation systems to improve production flow planning

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Abstract. The increased availability of data and computer-aided technologies such as MRPII, ERP and MES system, allowing producers to be more adaptive to market dynamics and to improve production scheduling. Integration of production scheduling and computer modelling, simulation and visualization systems can be useful in the analysis of production system constraints related to the efficiency of manufacturing systems. A integration methodology based on semi-automatic model generation method for eliminating problems associated with complexity of the model and labour-intensive and time-consuming process of simulation model creation is proposed. Data mapping and data transformation techniques for the proposed method have been applied. This approach has been illustrated through examples of practical implementation of the proposed method using KbRS scheduling system and Enterprise Dynamics simulation system.

1. Introduction

Increase agility and flexibility of manufacturing systems which allow to take measures to adapt production systems to produce many variants of products in variable production batches, requires implementation of innovative and intelligent technologies and changes in organizational structure. Implementation of lean concepts requires widespread use of tools supporting the management process and assessment of changes in production, configuration of production systems, planning, and scheduling at the operational level [1,2,3,4,5,6]. Increasing the efficiency of production planning and scheduling, which in today's enterprises is one of the areas where a large role is played by computer support, it is possible through the integration of Production Planning and Control (PPC) with computer modelling, simulation and visualization systems [3,7,8,9,10]. The use of Discrete Event Simulation (DES) systems allows quick verification of results obtained from PPC systems, the feasibility of production for developed plans for the sequence of orders execution, information on production order specifications and characteristics of production system. Simulation and visualization results could also be useful in the analysis of production system constraints related to the global and local viability of manufacturing systems (lack of deadlocks and starvations) and affecting the ability to meet the norms of production, which are not usually taken into account in production scheduling process.

The solution to problems mentioned above is integration methodology of production scheduling with discrete systems simulation systems, which is subject to considerations of this paper. The



proposed methodology is based on semi-automatic simulation models parameterization method based on data mapping and data transformation techniques in conjunction with the use of neutral data formats XML and XSLT [11,12]. The proposed method is intended for multi-assortment production systems. Innovative approach of the proposed solution lies in the universality presented methodology, which through the use of XML format is an open set of attributes of data exchanged between systems, scheduling and simulation. The method extends the static scheduling of pre-production analysis of production system state under typical disturbances or common problems (equipment failures, especially bottlenecks, the appearance of resource conflicts, deadlocks and starvations in the system). Set of topology systems classes or production flow types, for which the simulation model is created is also open. Furthermore the method of integration is not associated with a particular method of control (schedule, dispatching rules, the sequence of operations, etc.). In the next sections of the paper the practical implementation of proposed integrating method using KbRS scheduling system and Enterprise Dynamics discrete event simulation system will be presented.

2. Scheduling system

The Knowledge based Rescheduling System (KbRS) is a production scheduling system dedicated for non-rhythmic, multiassortment production together with the best possible utilization of production resources and taking into account accepted evaluation criteria. The basis for determining production schedules are the production system data set, technological and organizational data (information describing the production processes) along with the data of production orders – production routes, setup time, processing time, due dates, priorities, and the volume of production [1,13]. These data comes from many (often unrelated) sources of MRPII/ERP/CAPP systems. Due to the frequent gaps in information in existing databases, a part (or all) of the data can be entered into the system manually through a graphical user interface. After entering all the required data and defining input parameters the searching of available schedules is executed by two basic scheduling strategies: forward and backward. Schedules are generated by processes scheduling algorithms according to established common priority rules i.e. EDD (Earliest Due Date first), LDD (Latest Due Date first, LPT (Longest Processing Time first), SPT (Shortest Processing Time first) or Random, and set of the best solutions is saved. Production schedules are presented in form of the Gantt chart, an overview of evaluation indicators and analysis of individual schedules by other reports can be provided. The final decision on the selection and application of a schedule is taken by a the planner. The user interface (input data forms and results as Gantt's chart) of KbRS system is shown in figure 1.

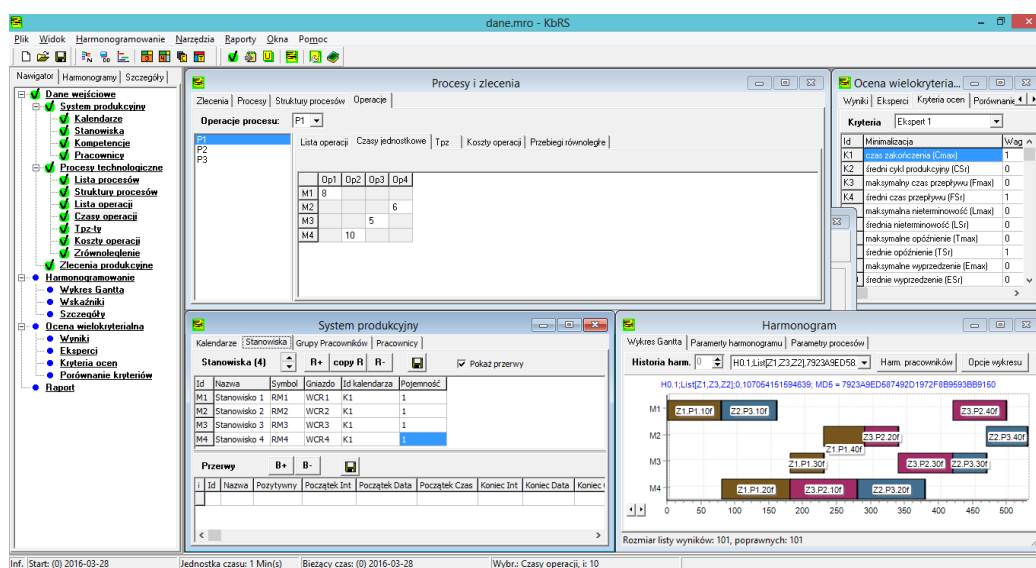


Figure 1. KbRS system.

3. Data integration tasks

Due to the necessity generate a detailed schedule at the operational level, scheduling systems are in place for the organization, where appears combines the complete information on production orders with a description of the production system. It is therefore the right “place” from which to perform the data-integration process with discrete-event simulation systems (DES) for verification schedules and perform analysis of production and storage system constraints related to the global and local viability of manufacturing systems, which are not usually taken into account in the production planning and scheduling process.

To create a data model for the exchange of data between KbRS and simulation systems, analysis of data used in these systems was required. Defined data model includes data on the production system (Ps), for which the schedule is created consists of a set of production resources M and a set of production orders (jobs) Po [13]:

$$Ps = (M, Po) \quad (1)$$

where:

$M = \{M_1, M_2, \dots, M_i, \dots, M_I\}$, I – the number of production resources,

$Po = \{Po_1, Po_2, \dots, Po_j, \dots, Po_J\}$, J – the number of production orders.

The production process can be carried out in the system according to the technological route, which defines the set of operations for a given product, component or element. An operation $O_{i,k}$ is described by:

$$O_{i,k} = (tb_{i,k}, t_{i,k}, ts_{i,k}, c_{i,k}) \quad (2)$$

where:

$tb_{i,k}$ – start date, $t_{i,k}$ – the operation time, $ts_{i,k}$ – the setup time, and $c_{i,k}$ – the cost.

3.1. Data model

In order to use the data as a source in the process of automatic simulation models generation it is necessary to define a neutral data model (not related to any particular system of scheduling), including all necessary components to build the model. Data model developed for integration needs [12], defines the data structure describing the manufacturing system resources, i.e. machines, work-in-progress storages, input and output warehouses, and data on production processes flow, i.e. technological routes, set-up times, cycle times, production schedule (sequences of manufacturing operations for all production processes in the production order on production resources) (figure 2).

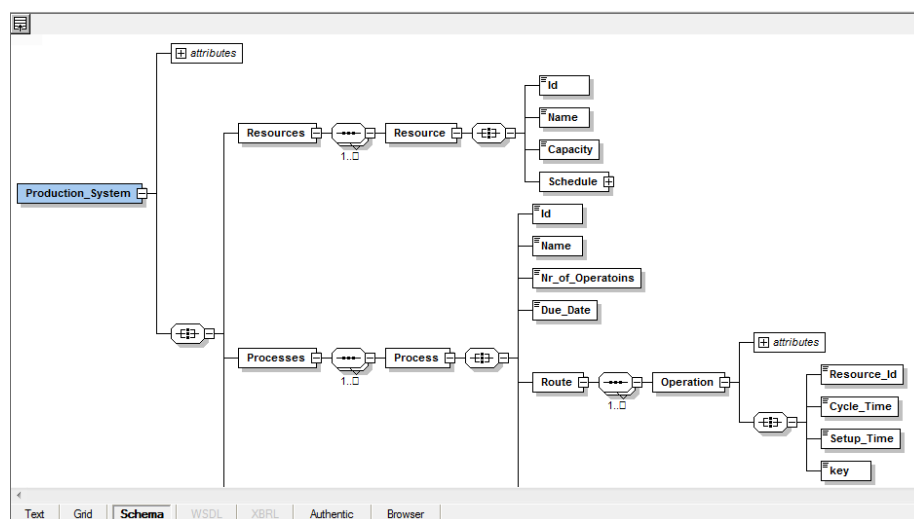


Figure 2. XSD Schema data model.

To define and store the data it was decided to use an XML technology for reasons of simplicity and usability, and wide application of XML technology in the production management and planning systems. XML-based formats have become the default for many PPC/ERP tools. Defining the structure and content of data was made in XML Schema. A sample of XML schema containing a definition of the XML document structure for the data for simulation model generator has been presented in figure 2.

The proposed integration concept is based on semi-automatic simulation models parameterization [13,14,15,16] method together with data mapping and data transformation methods in conjunction with the use of neutral data format in XML format defined in previous chapter.

3.2. Data mapping

Thanks to the fact that KbRS, like many other systems, enables to save the input data in XML format to convert and integrate data between KbRS and DES systems, data mapping technique based on XSLT language have been used. The mapping has been performed using the Altova MapForce Platform (offered by Altova® software company) for data integration. Altova MapForce is the any-to-any graphical data mapping, conversion, and integration tool that maps data between any combination of XML documents.

An appropriate connections of attributes between the two instances of data definitions (KbRS and neutral) and necessary data transformation using data processing functions allows for transforms data instantly (figure 3) or autogenerates data integration code (in XSLT Stylesheet format) for the execution of recurrent conversions in any available in the market processor XSLT.

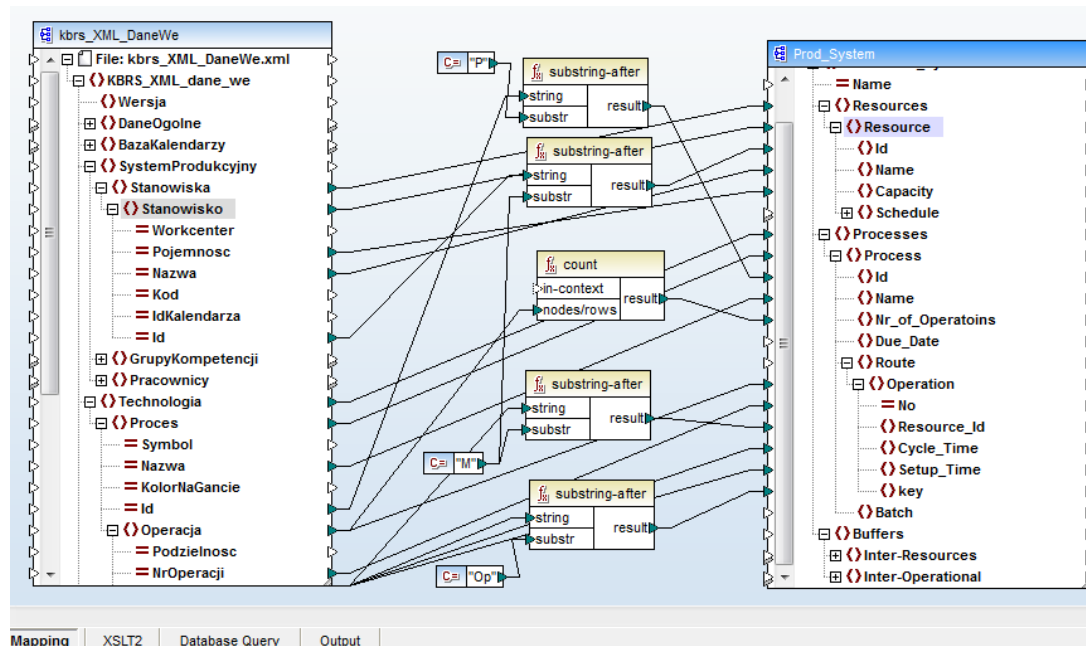


Figure 3. Data mapping (Altova MapForce).

3.3. Semi-automatic simulation model generation

For the purpose of semi-automatic simulation model generation the data transformation into the input file for the simulation software was used. Because the Extensible Stylesheet Language Transformations allowing to transform an XML document into another XML or any other file format it was decided to re-use data transformation technique. In this case, the output file will contain the script code into internal language of the simulation system.

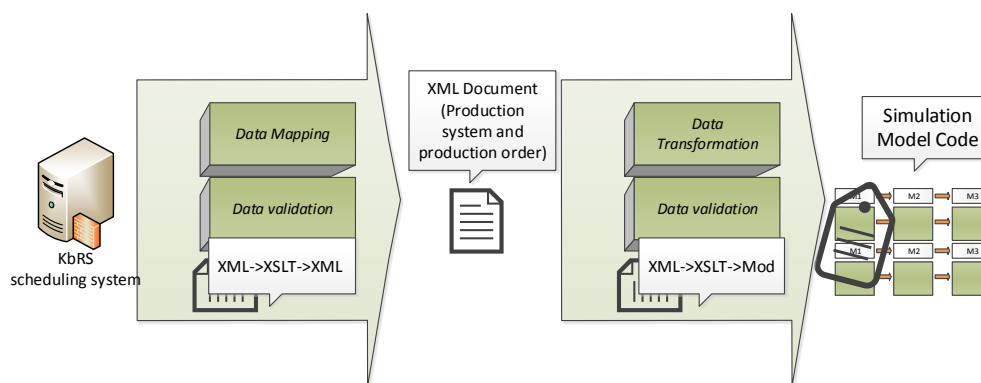


Figure 4. Semi-automatic simulation model generation.

The output code provides instructions to create complete manufacturing system – production resources, warehouses, input and output storages, products and information resources, i.e.: tables containing data about processing times and routes and scripts for the implementation of simulation and visualization. At this stage, files containing the script of the production system model, can be automatically open in a commercial simulation systems, such as Enterprise Dynamics (figure 4).

3.4. Exemplary model

Verification of the presented concept of scheduling and discrete event simulation systems integration was carried out to generate individual files, starting from the output file of KbRS system (figure 5a), through a file with a neutral production data format, ending on file with the model script code (figure 5b) and the final model for Enterprise Dynamics simulation systems and (figure 5c). Verification tests have confirmed correctness and completeness of the generated model. The model can be immediately used to perform the simulation experiments.

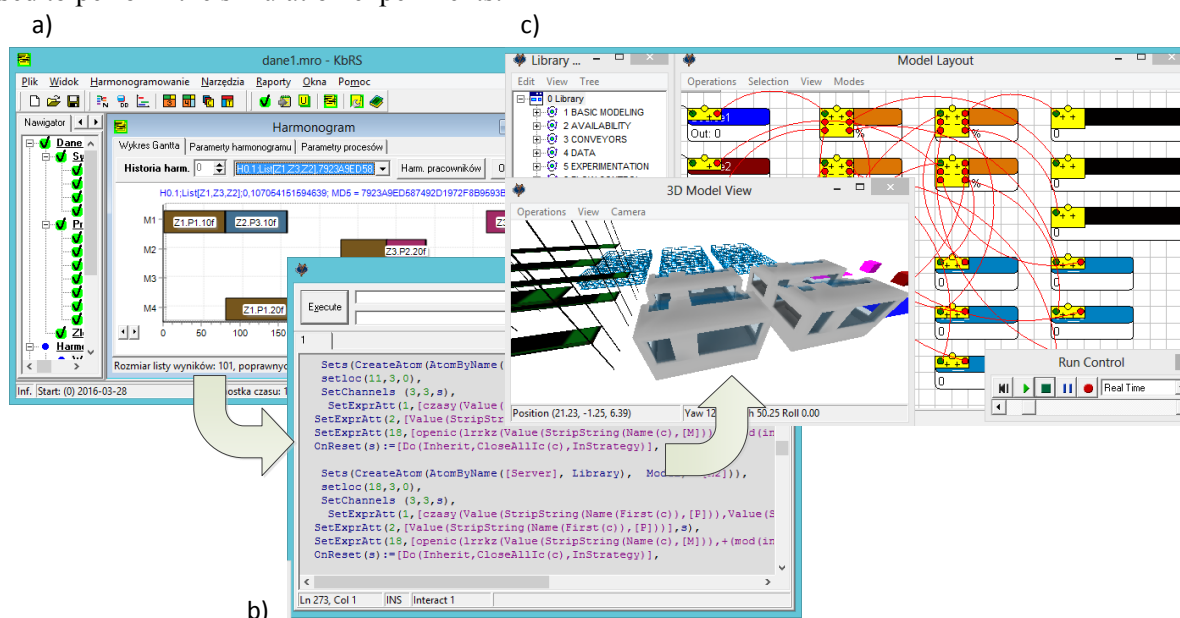


Figure 5. Semi-automatic simulation model generation.

Moreover, thanks to the fact that to build a simulation model specialized knowledge is not required, this method can effectively assist planners in decision-making in the area of scheduling and verification of orders.

4. Conclusions

In the paper a concept of integration of scheduling and discrete event simulation systems to improve production flow planning has been shown. Presented method can be successfully used with most computer simulation systems, which are characterized by object-oriented method of simulation model creating and offers the ability to write the model objects in the internal scripting languages. Industrial implementation of proposed concept could significantly increase the efficiency of production scheduling systems. Future research includes extension of data models and applications of the method to other domains.

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