Production Preparation and Order Verification Systems Integration Using Method Based on Data Transformation and Data Mapping

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Abstract. Fast growth of the SME sector, increasing demands of customers and dynamic market force the producers to lower production costs and to use new IT tools in production. The paper presents method of integration of preparation of production and production planning systems, such as SWZ and PROEDIMS. The system constituted in this process will enable SME entrepreneurs to take correct decisions connected with planning and controlling production. The integration will be achieved by methods of data transformation and data mapping using XML language. Due to this integration PROEDIMS system will be enriched with the module supporting verification of production orders, using constraints satisfaction and depth-first search (DFS) algorithm with backtracking.

Keywords: production planning, integration, xml, constraint satisfaction, organisation variants.

1 Introduction

Nowadays, production enterprises operate in a very dynamic environment. Global market, fierce competition and constantly changing customers' demand lead to shortening product life cycles, together with increasing the complexity of products. These factors are forcing manufacturers to adapt to new circumstances and to invest in increasingly sophisticated and innovative technologies. Along with these changes there is a need to develop and implement new production systems planning methods [1, 2]. These demands concern mainly small and medium-sized enterprises (SME), which in the EU constitute 99.8% of all non-financial business economy enterprises, which represents almost 70% of total employment in the private sector. SME companies are divided into medium-size (fewer than 250 employees), small (fewer than 50 employees) and micro-enterprises (employing fewer than 10 people). In the manufacturing sector, SMEs constitute 99.2% of enterprises. Micro-enterprises, which currently account for 92% in the SME are undergoing especially high growth in recent times [3].

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For SMEs segment companies, it becomes an imperative to use of computer aided decision support systems in production planning process, in particular with regard to decisions on the possibility of production order implementation which guarantees realization of the production job according to the production order, with the lowest level of capital invested. Support systems in SME sector functioning in various areas related to the preparation and production planning are usually not integrated. Lack of integration between these systems affects the efficiency in their use and is a potential area where it is possible to increase efficiency, which is associated with reduction of costs for SMEs.

2 Problem Formulation

Because of the wide range of activities, high cost of implementation and a need to apply changes within a company's structure, production management systems available on the market are implemented mainly in big enterprises. For SMEs (and particularly for micro companies) the cost and time of implementation of MRPII / ERP class systems are main reasons due to which they are not implemented. The situation of SME presented in the introduction, connected with rapid development, execution of multi-assortment production realized in small batches which is often a reaction to the sudden demand (MTO), force companies to look for tools to support decision making at the operational level and orders management.

The necessity to build IT tools involves a need to develop new decision-making support methods, in particular with regard to decisions on the possibility of the new production order acceptance, realization of the production job according to the production order, with the least cost of production. In the paper results of the implementation phase of the exchanges data module are presented. The exchanges data module is necessary in the process of integration of production preparation module of PROEDIMS system with production orders verification SWZ system for multi-assortment, concurrent production. The constraint satisfaction techniques are used in SWZ system. Sufficient conditions for all possible solutions of production flow filtering are defined using this approach and it gives a set of admissible solutions for both the customer and the producer demands.

Meeting this goal will require modifications to independent systems operated in areas related to the preparation and production planning. PROEDIMS system is being developed at the Institute of Machine Technology and Automation at the University of Technology in Wroclaw. SWZ system is being developed at the Technical University of Silesia. Integration of these systems will be implemented through the development and implementation of a dedicated interface for data exchange. In the paper the method of formal description of production processes data structures taking into account available resources of production system using Extensible Markup Language (XML) is presented. The exchanging data interface module based on techniques of data transformation and data mapping supporting the integration of computer applications is also presented.

3 SWZ and PROEDIMS Production Planning and Preparation Systems

3.1 PROEDIMS System

PROEDIMS system belongs to a family of products which manage product data and processes in the enterprise. PROEDIMS enables creation, collection, management and propagation of all data related to the product throughout the product life cycle and all information and data necessary for the proper functioning of the company.

This system supports various areas and activities related to the product and company activities, starting from the conceptual phase, throughout design, process management, logistics, customer and suppliers relationships management, to the maintenance and servicing of products [4]. Phase of the project discussed in this paper, is related to the integration of the SWZ system with PROEDIMS, and intends to complement the PROEDIMS with the module associated with the jobs scheduling on system resources. Input data of SWZ system transferred from PROEDIMS system allows determination of the sequence of operations on the resources of the production system. After transferring it back into PROEDIMS, the data will become the basis to generate production system work schedule.

3.2 SWZ System

Production Orders Verification System – SWZ is a computer implementation of methods supporting rapid decision taking on the acceptability of a production order for multi-assortment repetitive production systems. The current state of knowledge and achievements in the area of scheduling significantly limit their practical application. Determination of the optimal schedule, in most cases is a NP-hard problem (NP-complete). Algorithms with polynomial computational complexity for NP-hard problems probably do not exist, which practically means that for most manufacturing systems it is not possible to achieve the optimal solution in reasonable time, due to the number of resources and jobs. This necessitates the abandonment of determining the set of all possible solutions for the determination of a subset of feasible solutions. In real production systems it is required not only to find the best possible solution, but to find a solution possible to reach in a reasonable time (a solution acceptable) and the one that can be accepted given the existing constraints. The group of methods that guarantees obtaining an acceptable solution includes the artificial intelligence methods, heuristics and meta heuristics, random search methods, simulation methods or constraints satisfaction [5].

The support rapid decision-making methodology on the acceptability of a production order using constraints satisfaction techniques and is tantamount to testing a sequence of arbitrarily selected conditions. The fulfilment of all conditions (their conjunction) guarantees the possibility of order execution (Fig. 1). Lack of solution provides information about the necessary abandonment of specified conditions of the order, or having to meet the needs associated with an increase in available capacity, storage space, etc.

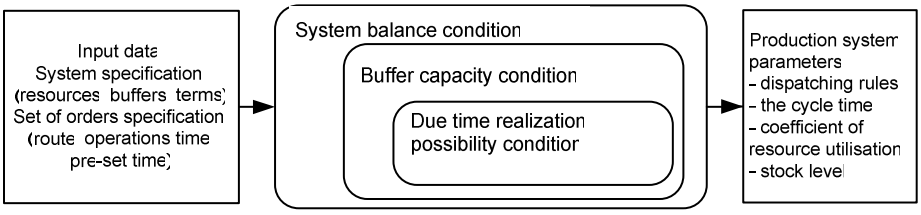

Fig. 1. Procedure of the acceptance of the production orders set for realisation in the system

Sufficient conditions, which are used in described methodology, have been designated for the production system and production order identified constraints. The conditions include: [1, 6, 7]:

- system balance condition - takes place when the number of processes introduced into the system is equal to the number of processes leaving that system during one system cycle,
- buffer capacity condition - the capacity of the inter-resources buffer is equal or bigger than the realization number of the process during one system cycle.
- due time realization possibility condition – processes included in the production order will be executed within the due time required by the customer.

In previous works [1, 2, 8] it has been proved that for multi-assortment repetitive production (for the steady state of system) fulfilment of the system balance condition and the buffer capacity condition provides a qualitative functioning of the system (deadlock-free behaviour of a system). However, the growing market requirements for increasingly varied products cause that production is realized in short series, and thus the process flows are often changed. A significant problem is therefore a transition from one expected steady state of the production system to another one.

In the considered methodology the deadlock protection method (which guarantees functioning of the system for transient phases) is used and it establishes the sequential ordering of the processes realisation in the dispatching rule (for the start-up and cease phase). Start-up rule realizations fill up the additional number of elements into the inter-resources buffers, which guarantees deadlock-free system behaviour and synchronises the production flow into the expected steady state. Similarly the cease phase applies to the single process completion or final production completion. The transient phase includes the starting-up phase and cease phase as well. The transient phase consists in the transition from one expected steady state of the system to another one [9]. During the starting-up/cease phase the starting-up/cease rules are determined.

The determination of the starting-up/cease rules consists of the following stages:

- the identification of close cycles in the system structure,
- the determination of the multiplication of the process realized during the starting-up/cease rule.
- the determination of the processes realization sequence in the starting-up/cease rule.

The cycle of mutual expectations is one of the conditions necessary for the deadlock occurrence. The equivalent to ensuring deadlock-free system behaviour is avoiding the appearance of that cycle through the allocation of the dispatching rules at the resources. According to the production system topology, the cycle of mutual expectations can take place only at the shared resources belonging to the closed cycles. Thus, at first the closed cycles should be identified. For the identification of the close cycles occurring in the production system the contour search algorithm adopted from Graph Theory is used [8]. It is possible because a graph is a model that enables the description of a production system structure. The production resources are represented by the graph vertices and the parts of the production routes allocated between each pair of the neighbouring resources are represented by the ordered pair corresponding with the graph edges. The elementary contour from the terminology of Graph Theory is adequate to the basic cycle from the terminology describing the production system structure. The identification of the graph contours requires the application the deadlock protection method. That method requires the action consistent with the consecutive steps of the contour graph algorithm including the depth-first search (DFS) algorithm with backtracking. According to the DFS algorithm one starts from the start vertex and moves along the path generated by the successors list. The successors of checked vertex create the tree of next successors. The consecutive vertices are checked until it hits a vertex that has no non-checked successors. Then the search backtracks, returning to the most recent vertex it hasn't finished exploring. When all routes starting from the x vertex are verified it is necessary to choose another vertex and repeat all procedures. It means that the recurrent procedure of the graph contours search is considered. The deadlock protection method enables to check, whether the contours in the given graph exist and find the sets of the graph vertices forming the contours. The pseudocode of the contour search algorithm presented in Fig. 2 can be found at [10].

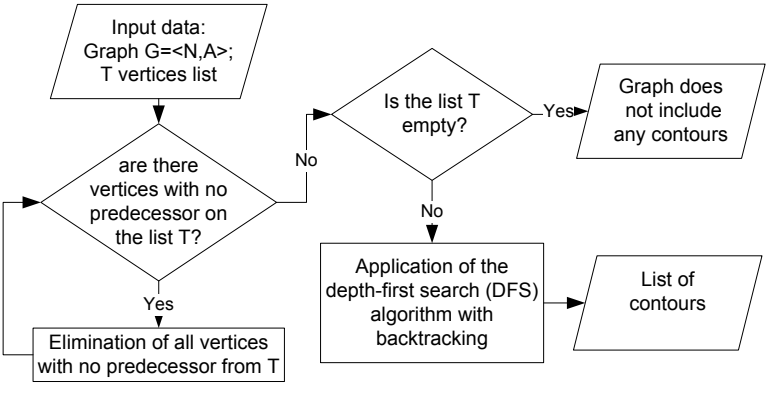

Fig. 2. Contour search algorithm

The result of that stage is the list of the resources belonging to the basic cycles. If the list of resources is empty, the determination of the processes realisation sequence in the starting-up rule is useless. The support rapid decision-making methodology on the acceptability of a production order which uses elements of constraints propagation

method and DFS algorithm has been implemented in the SWZ. For the data describing the system and the production order dispatching rules are determined, together with quantitative and qualitative indicators of the production system. It gives the possibility to form high-level indicators of production, such as resource utilisation and level of work in progress.

4 SWZ and PROEDIMS Exchange Data Module

The exchange of data between systems, due to the versatility and convenience in use, is achieved using the Extensible Markup Language XML [11]. XML is currently very popular and much more often used in the exchange and analysis of data collected and processed in IT systems, supporting enterprise management at different levels and functional areas. XML is designed to represent different data types in a structured way. The choice of XML for integration PROEDIMS and SWZ systems, as the language for collecting data, was dictated by the fact that XML is currently very popular and used more often in areas related to the exchange and analysis of data in enterprise management systems [12, 13, 14]. For production system and production order models developed the document structure definition using XML Schema. The choice was dictated by the way of writing the definition, which is also implemented using XML, and the fact that XML Schema allows to define data type constraints. It also allows to create new definitions of the structure or combining information from several schemes, which is important in the process of acquiring data from enterprise resource planning systems.

Developed for integration needs, XML schema in PROEDIMS system has been divided into the following modules:

- Planning - containing data on production orders and operations for scheduling.
- Production - containing data on orders and related operations currently in progress,
- Resources - containing a list of production resources with the calendars of availability.

Developed XML schema for SWZ system defines the structure of an document describing the production resources consisting of manufacturing system, production processes data and production flow data.

The next step in the implementation of a systems integration project was creation of a transformation data module between different data models. The transformation process was divided into two concurrent stages resulting from the functional areas of integrated systems:

- The stage of calculation, associated with the change of the generated sequence of the tasks on the resources of the schedule used by the system PROEDIMS. This stage is related to the fact that the system implementation schedule PROEDIMS operations on resources is associated with the calendar availability of productive resources, which is not taken into account by the SWZ system.
- The stage of data mapping stored in PROEDIMS data model and data set in the previous stage with the data which is stored in SWZ data model.

For the purpose of transformation process automation was used Extensible Stylesheet Language Transformations XSLT [15]. XSLT is used to convert an XML document into another document, Web page, a text document or other file type. Implementation of the conversion process can be performed using the processor delivered as standalone products, or as components of other software including web browsers, application servers or other open-source software. Calculations on the data are realized with the use of XML Path Language.

Data module was implemented in SWZ system. Functional diagram of a transformation module was shown in Fig 3. Implementation of the transformation data module in SWZ system consists of the following steps:

- loading the XML file, containing information on the planned production, from the PROEDIMS,
- validation of the loaded file based on XML Schema,
- transformation of the file using XSLT (mapping data and calculations using XPatch),
- generating an XML file for SWZ,
- validation of the loaded file based on XML Schema.

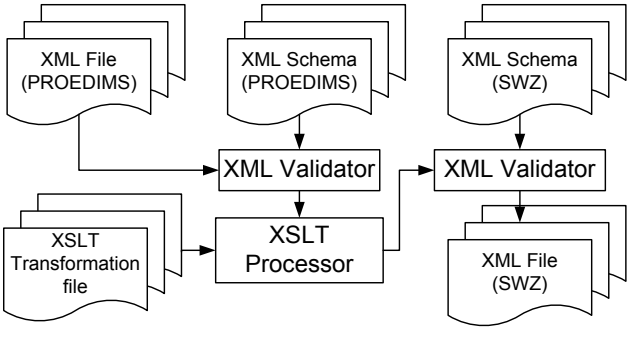

Fig. 3. Transformation data module

Elements of the structure of input and output files are converted according to an order resulting from the requirements of an XML document formats through properly addressed references to the tags (nodes) using the XPatch language. In the same way the next phase will be conducted involving the integration of processing and transmitting information containing the schedule generated from SWZ to PROEDIMS system.

5 Summary

Presented in the paper method of exchanging data between different preparation and planning of production systems, based on data transformation and data mapping allows integration of the systems described in the paper. The proposed integration module will increase the efficiency of planning departments and performance of production systems, which is associated with reduction of costs for SME. As a result

of the development and implementation of the system it will be possible to increase the effectiveness of the integrated decision-making areas. It will also allow SME sector companies to create virtual organizations. The prototype of the management system dedicated for SMEs will be the final result of the project.

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