The role of the production scheduling system in rescheduling

K Kalinowski1, C Grabowik1, W Kempa2 and I Paprocka1
1Silesian University of Technology, The Faculty of Mechanical Engineering, Institute of Engineering Processes Automation and Integrated Manufacturing Systems, Konarskiego 18A Str., 44-100, Gliwice, Poland
2Silesian University of Technology, Faculty of Applied Mathematics, Institute of Mathematics, Konarskiego 23A Str., 44-100, Gliwice, Poland

E-mail: krzysztof.kalinowski@polsl.pl

Abstract. The paper presents the rescheduling problem in the context of cooperation between production scheduling system (PSS) and other units in an integrated manufacturing environment – decision makers and software systems. The main aim is to discuss the PSS functionality for maximizing automation of the rescheduling process, reducing the response time and improving the quality of generated solutions. PSSs operate in the meeting of tactical and operational level of planning and control, and play an important role in the production preparation and control. On the basis of information about orders, technology and production system state (e.g. resources availability) they prepare and/or update a detailed plan of production flow – a schedule. All necessary data for scheduling and rescheduling are usually collected in other systems both from organizational and technical production preparation, e.g. ERP, PLM, MES, CAPP or others, as well as they are entered directly by the decision-makers/operators. Data acquired in this way are often incomplete and inconsistent. Therefore the existing rescheduling software works according to interactive method – rather support but does not replace the human decision maker in tasks planning. When rescheduling, due to the limited amount of time to make a decision this interaction is particularly important. An additional problem arises in data acquisition, in the process of data exchanging between systems or in the identification of new data sources and their processing. Different approaches to rescheduling were characterized, including those solutions, where all these operations are carried out by an autonomous system and those in which scheduling is performed only upon request from the outside, for the newly created scheduling data representing the current state of the production system.

1. Introduction
The complexity of scheduling problems in real production systems requires a considerable amount of calculation in determining schedules. Therefore, solving of decision-making problems at all levels of planning and control is done by extensive use of dedicated software [1, 2]. Creating a schedule manually, by decision makers, even with a relatively small number of orders and operations, allows the construction of one or a small number of schedules, with unknown quality. Determined by this way a feasible solution is based largely on intuition and chance, and can hardly meet assumed goals. The use of appropriate scheduling software allows, among others, for searching larger area of solutions space in shorter time, and consequently for finding a better solution, closer to optimal. Despite numerous researches on production scheduling issues, describing detailed models and

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methods and techniques for obtaining solutions, very little space is dedicated to their practical implementation [3, 4].

From a computer system supporting scheduling of manufacturing systems a certain set of functions is expected. The scope of this functionality depends on many factors connected with particular implementation in a given a production environment, the nature of applied technologies, existing software and knowledge and experience of decision-makers. Scheduling system requirements may relate to: the scope and complexity of handled models of scheduling problem (α|β|γ), generating and evaluating of solutions, interactivity and the requirements of the user and systems interfaces, possibilities for analyze of production capacity and throughput, operation in real-time conditions, connections with other software systems in the enterprise etc. [5]. In the paper the most important requirements of PSSs functionality in an integrated environment are discussed.

2. Integration and data exchange
Generating of correct solutions in a short time requires direct accessing to the appropriate data. These data can be imported from the external sources or entered directly by the user. Effective work organization in the enterprise requires a coherent information system, carried out mostly in the form of an integrated system based on a common, central or distributed database. Some companies, however, has not implemented this type of information systems and uses separated software with local databases or even only paper documentation. Manual entry or periodically copying data into/between software’s databases of production systems, without adequate infrastructure of data exchange interfaces of resources, significantly reduces the usefulness of the scheduling system and contributes to delays in data processing and responding to the unexpected events. The lack of access to current data causes difficulties in making the right decisions, at every level of management.

The lack of an integrated environment requires acquiring data from independent systems. Then it is necessary to carry out the process of data mapping in order to accurately transforming of their internal structure of the system and testing the data integrity. Integration at the level of the exchange of data between systems can be realized in different ways [6]:
- by a common database, where one of the systems directly accesses the database of other system or new, common database is created,
- by the use of separate databases and the development of a common format for data exchanging.

In order to provide the access to current data the scheduling system should be integrated with other systems, both in the field of organizational and technical preparation and production control i.e.:
- ERP (Enterprise Resource Planning), or less complex systems of MRP (Material Requirements Planning) or MRPII (Manufacturing Resources Planning), PLM (Product Lifecycle Management), PDM (Product Data Management), PMS (Project Management Systems), BPM (Business Processes Management),
- MES (Manufacturing Execution System), SCADA (Supervisory Control and Data Acquisition) or systems of CAx class, e.g. CAPP (Computer Aided Processes Planning).

Figure 1 shows the connections for the exchange of data in the ERP / MES / SCADA class of planning and control of production flow systems. Among the required input data for scheduling, acquired from the ERP class system, the following can be distinguished: information related to the description of parameters of the production system model containing resources availability, the actual packages of orders, criteria for schedules evaluation, as well as conditions and instructions for rescheduling [7]. The required data on the state of the production system are derived from the SCADA system [8, 9, 10, 11, 12].
The current development level of information systems used in enterprises, with built-in modules and the application of uniform standards for data exchange simplifies the process of integration between different systems, reducing both time and cost of implementation. The most commonly used data exchange standards are described by ISA (ANSI / ISA-95, ANSI / ISA-88), OPC, OAGIS, and MIMOSA standards [13, 14, 15, 16].

3. Custom and generic software
Siemens Computer-aided production scheduling can be implemented by dedicated software (custom software) or in the form of specialized modules/ components of standard system (generic software), the most common of ERP or MES class systems. A review of selected scheduling systems and to compare performance of their functions was presented in [17]. Beyond the classification of commercial dedicated and standard software an academic solutions are also described there. The generality level of standard systems allows their wide applications in various manufacturing companies and industries. The implementation of such kind of systems in the particular manufacturing plant often requires from the company carrying out a series of organizational changes, structures and implemented procedures. The universality of this approach, however, may have a weak side – created solutions may not include all the required constraints and evaluation criteria, resulting in the need for making significant corrections of generated solutions. An alternative to generic systems, which are popular rather in medium and large sized manufacturing systems, are dedicated, custom systems. This type of software is created from scratch or adapted from solutions used in another companies with a
similar profile of production. The advantage of the generic software implementation is the ability to obtaining a significant range of required functions with little effort of required organizational changes and receiving the desired functionality of the software in less time. For creation or adaptation of dedicated solutions motivates: similar architecture of scheduling system, existing data exchange interfaces and the original user interface concept, large amount of non-standard functions and activities that are characteristic for a certain class of manufacturing systems, etc.

4. Expectations of the production scheduling software
Within the basic functionality of production scheduling system two functions can be distinguished: scheduling, that means the off-line schedule preparation, and rescheduling associated with on-line activities. The combination of both these functions is known as predictive-reactive scheduling. Therefore, these functions of the system should provide repairing of the adopted schedule, responding to any problems resulting from unexpected events in the production system. Among the most important decision-making problems in rescheduling the following can be mentioned: detection of disturbances and identification of their parameters, the decision about the schedule correction – immediate, postponed or not required, making proper changes in the scheduling model, determination of the rescheduling method, creation a set of operations to reschedule and a set of evaluation criteria, etc.

When creating software for rescheduling, it is important to ensuring data about the parameters of disturbances and the role of decision maker in modifying the input data for scheduling, determination of the rescheduling method, creation a set of operations to reschedule and a set of evaluation criteria. For this reason the ‘a priori’, ‘a posteriori’ or interactive method can be introduced [18]. The interactivity of the system allows the user taking an active part in the process of creating a solution. Depending on the applied method of interaction the participation of decision maker in the process of scheduling can significantly affecting the quality of the final solution by including additional, not included in the model conditions or preferences, e.g. informal evaluation criteria. Interactivity requires the presentation of the temporary results of calculations at the appropriate level of detail, in a clear and accepted (by a user) manner. Enabling interactivity is closely related with the development of a user interface. It should provide access to relevant information, depending on the user rights.

Rescheduling can be performed may be carried out at different intervals - at regular or irregular intervals. In the first case, the schedule is updated at predetermined time intervals. This method is often used in industrial enterprises, where data on the state of the production flow are not available and processed on-line, e.g. if are gathered in the traditional way, using paper forms. Prepared and revised schedule is valid for the entire cycle. The basic problem in the periodic rescheduling is the determination of an optimal rescheduling period, which should takes into account the frequency of disturbances occurring, their overall impact on the production flow and the system condition and also effectiveness parameters of resources. A main disadvantage of only periodic revised scheduling is outdating of the schedule in case of major disruption and shifting decisions on correction in time. The problem of continuing assigned tasks in presence of disturbances are solved locally, by lower-level manufacturing workers, dispatchers or operators. The undoubted advantage of this method is higher scheduling stability compared to rescheduling carried out after a single event.

Because of the strong dependence of certain scheduling algorithms on the production system configuration, the type of orders (structures of processes), given constraints and criteria a desirable feature of the system can be automatic model detection. The possibility of scheduling problem classification can greatly relieve the user of the system in the selection of appropriate algorithms and reduce the time to determine a solution. It is also important that in many cases, the given problem can be solved using different algorithms in parallel – the system should guarantee their execution and comparison.

A desirable feature of the system is the ability to carrying out scheduling simulations in various configurations of the production system, and analyses related to the resources load, i.e. the identification of "bottlenecks" and under loaded resources [3, 19].
In some cases, the scheduling system may be required to operate in real time [20, 21, 22]. The correctness of operation in real time depends on the result of the conducted calculations and also the time at which results are obtained. Therefore, in such systems two states are distinguished: internal and external. The calculations based on registered at a given moment, and entered into the scheduling system, the state of the production environment, are defined as the internal state. The current status of the manufacturing system, defined as external state, may change over time and make, obtained in the meantime solutions, out of date. This situation makes it necessary to establish criteria for limiting the time to determine a final solution. The sources of time type of constraints are different kinds of unforeseen events occurring in the production environment and affecting its state. The time requirements, depending on the application, may range from milliseconds, minutes / hours, or longer periods of time and may vary depending on the decision situations, even within the same environment. Another important issue is the limited and guaranteed time for creating a solution. According to the environmental requirements and potential consequences of missing the deadline for obtaining a solution by the system three basic types of real-time systems (RTS) can be characterized:

- **hard RTS** – systems with absolute time limits, in which exceeded the deadline invalidates the solution and is dangerous or catastrophic for the functionality of production environment,
- **firm RTS** – systems with absolute time limits, in which exceeded the deadline invalidates the solution without a strong impact on the operation of production environment,
- **soft RTS** – systems with “soft” time limits, in which the delay of due date reduces the usefulness of solutions but only after exceeded the deadline solution shall be cancelled.

The system requirements do not need to be associated with only one type of real-time system. The given system can handle a set of events, in which only some of them requires of operating in absolute limit conditions. Scheduling software in manufacturing systems in most cases can be treated as a soft real time system.

5. Conclusions

The role of production scheduling software in the integrated manufacturing environment is discussed in this paper. Possible ways of integration and the key software types, from the field of organizational and technical preparation and production control, supporting scheduling system are described. The basic functionality of the scheduling software for maximizing automation of the rescheduling process, reducing the response time and improving the quality of generated solutions were also identified. The correctness of the generated solutions by the scheduling system depends strongly on the availability of current data. In practice, the production systems in which data are collected manually or stored in separated systems are not capable to the proper response to disturbances. In relation to software development main advantages and disadvantages of using custom and generic software were mentioned. Particular attention was paid to expectations of the production scheduling and rescheduling software. Due to the dependence of unexpected events interactivity requirements relating to the system were not questioned here - conditioned by the need to participate the decision-maker in developing schedules. So the role of the system is still supporting but not replacing the human decision makers.

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