PROBLEM OF DEFINING KNOWLEDGE FOR PURPOSE OF PRODUCTION MANAGEMENT

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Abstract

Production management was often deemed as an activity subjected to relatively simple rules defining the ways and criteria for operation. It was thought that it was possible to establish constraints and relationships between production tasks and technical and technological capacities. The criterion function, defined as execution of tasks in timely manner, was also considered to be easy to formulate. Formulation and optimization of such task appeared to be free of bigger analytical problems. In practice, however, it is impossible to present so defined problem in a pure form. The technical, organizational and logistic aspects should not be considered separately from other limitations defining them as well as opportunities originated from management activities, such as marketing, finance and human resource management.

This paper describes the problem of developing production control systems taking into account not only technical limitation but also the overall activity of economic entities on the market. We define the problem of calendar planning in the discrete production systems. Moreover, we propose the task classification scheme by knowledge base and methods of acquisition and defining of knowledge. The application areas for the planning supporting systems based on the presented principles are also described. This problem is presented on an example of an intelligent production planning system at steelworks. The tools used for construction of the knowledge base about the problem and conceptions of verification and performance of systems forming an application of knowledge are discussed.

Introduction

The ability to set a schedule of operation execution is a key to production effectiveness of enterprises [5]. This problem is termed as a calendar planning [9] (scheduling, time planning). This consists in setting a time of commencement of all operations for known limitations (determined by so called effective productivity) in such a way that the criterion defined by a decision maker is observed. There are many various problems termed a calendar planning, but substantially differing from each other so can not be described with a single model. For example, in case of a project management problem we are faced by the activity scheduling. This is a quite different problem than that connected with operational planning of a direct-line production. In this paper we focus on time sequencing and classification. This regards to the discrete

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production systems, thus those in which the flow of materials and half finished products is performed in a form of individual elements subjected to technological operations at consecutive work-places. The element processing determined by subsequent operations is termed a production task (job). The problem of task sequencing in the flow production system belongs to one of simplest and relatively universal models [7]. This describes a situation when we deal with \( n \) production tasks performed on \( m \) machines. This model enables us to solve the problem of calendar planning in great many of cases (in machine-production, in management of computer processors etc.). Unfortunately, quite "strong" limitations of definition of the model exclude a large group of actual problems, which cannot be described in such a way. This regards mainly to such problems as:

- dependence of the set-up time on task sequence,
- occurrence of common operations, when many production task are carried out simultaneously (for example: metal casting in a foundry),
- opportunity to accumulate inter operational inventories and its exploitation in the case of process disturbances,
- occurrence of additional time limitations.

At present we have at our disposal the adequate numerical methods which allow solution of each of these problems as an individual optimization problem [1,9]. It is also possible to convert actual problems in such a way that the models of calendar planning problem solution should be supplemented with other methods, e.g. models for solving the division problem or stock optimization. However, this greatly complicates the problem as well as its application.

An additional difficulty in formulation of an applicable time planning model arise from the criterion function. In the classic approach to the problem of task sequencing the "natural" criteria for evaluation of quality of sequencing such as minimizing of the makespan, i.e. time of task completion in the system, mean flow time in the system and mean tardiness are most frequently used.

Sometimes in order to take into account additional criteria, priorities are assigned to tasks and then the criterion function can take a form of weighted mean. Even in this case an objective assessment of solution cannot be achieved in all conditions. This results from difficulties connected with establishing of appropriate weights as well as from the fact that not all criteria are comparable among each other.

The formulation of an adequate model considering all stated restrictions does not guarantee that the optimal solution is achieved. Majority of models used in time planning reduce this problem to the NP-hard problem. There are two approaches to solution of this problem consisting in application of [7]:

- exact algorithms such as branch and bound method enabling search of the entire space,
- heuristic polynomial algorithms leading to approximate solutions.

The exact algorithms are not widely used due to technical limitations which exclude solution of complex problem within sufficiently short time. However, the heuristic algorithms can lead to solutions which are close to optimal ones, but assessment of such solutions is difficult and its universality is strongly limited. Applying the heuristic algorithms it is assumed that the mechanism causing that one solution is more favorable than another, remains unknown and unknowable. It is possible only to
evaluate solutions with respect to a selected criterion function. The algorithm itself enables an elimination of worse solutions and achieving solutions which can be close to an optimal one through series of random experiments or calculations based on empirical formulas. In both cases (for exact and heuristic algorithms) it is necessary to formalize the problem in a form of procedural knowledge, thus allowing an unique connection between a criterion value and parameters resulting from task sequencing with calculation formulas.

**Conception of planning system with knowledge base**

It seems that it is possible to apply a quite different approach to the presented problem. This consists in replacing the procedural description with declarative record of knowledge about the problem and criteria for solving it. In this case, there is neither necessity for unique determination of the model nor selection of a synthetic criterion function. Each unit problem can be described individually and the decision maker can define his own objective function. In this paper we present a procedure for construction of such systems, which would be able to solve series of various problems related to calendar planning. It is necessary to define an area of future possible applications for the systems based on declaratively written knowledge about calendar planning. Below we consider a class of time planning problems of the following attributes:

- the systems resolve problems of calendar planning in discrete production systems and combination of some of production tasks during performance of some operations is permissible,
- a set of \( n \) indivisible production tasks \((T_i)\), for which execution sequence should be established,
- at least one criterion enabling assessment of quality of ordering.

All other information regarding to nature of the process should be set individually for each particular case.

In addition it was assumed that there is possibility to decide which ordering of each pair of production tasks is permissible and favourable on the base of expert knowledge. Thus, the sequencing problem is reduced to deciding on ordering relationship for consecutive pairs of tasks. In order to avoid any misunderstanding, further in this paper we use \( \{T_i, T_j\} \) to denote a sequence in which task \( T_i \) should be performed before task \( T_j \). The ordering scheme can be written as follows:

```
BEGIN
FOR i:=1 TO n-1 DO
BEGIN
    FOR j:=j+1 TO n DO
    BEGIN
        IF i = 1 THEN
            change:= (sequence \( \{T_j, T_i\} \) is more favourable than sequence \( \{T_i, T_j\} \))
        ELSE
            change:= (sequence \( \{T_{i-1}, T_j, T_i\} \) is more favourable than sequence
```


\( \{T_{i-1}, T_i, T_j\} \)

END;

END;

END.

Determination of value for the logical variable change is simple in case of one criterion (e.g. the set-up time). However, this should be performed on the base of multilevel inference procedures which can be executed through the system with knowledge base in more complicated systems. Thus, the system of calendar planning is a hybrid system combining the simple sorting procedure with decision system equipped with base of knowledge using for assessment of the ordering quality factor.

**Representation and acquisition of knowledge**

Construction of an adequate form of knowledge representation, i.e. knowledge base, belongs to the most important problems connected with building the system with knowledge base. The simplest way of knowledge acquisition is verbal recording of rules determined by an expert (experts). However, many ambiguities occur in the problem under consideration, so numerous criteria as well as the quantitative and qualitative parameters should be taken into account at the same time. The verbal write of knowledge can lead to an incomplete or internally inconsistent knowledge base and the process of its formation can be difficult. Thus, formalization of the knowledge acquisition and defining process is needed. It is assumed that during knowledge acquisition process for purpose of system determining the most favourable sequence for execution of production tasks the technique which consist in generating a decision tree on the base of given decision tables \([2,3]\) to be applied. Because of many criteria which are considered together, it is necessary to create a series of decision tables corresponding to each criterion and one table merging partial solutions into a final decision. When performing the inference procedure the quantitative variables (e.g. set-up times) are transformed into linguistic variables in order to enable comparison among criteria. For example, if for task sequence \(\{T_i, T_j\}\) the set-up time is 10 units while for sequence \(\{T_j, T_i\}\) is equal to 2 units we can assign the unfavourable linguistic value to sequence \(\{T_j, T_i\}\) and favourable value to sequence \(\{T_j, T_i\}\).

Thus we deal with two-element set of objects (sequence \(T_j, T_i\) or \(T_{j-1}, T_j, T_i\) and sequence \(T_i, T_j\) or \(T_{i-1}, T_i, T_j\)) described by the set of attributes:

\[
A = \{ a_1A^1, a_2A^2, ..., a_mA^m \} \tag{1}
\]

i.e. each attribute can take values from the finite set \(A\) and on this base we can include an object into certain class defined uniquely by an expert:

\[
C = \{ c_1, c_2, ..., c_m \} \tag{2}
\]

In case of particular partial criteria these classes determine whether given sequence is very favourable, favourable, neutral or unfavourable etc. while for final solution we have two classes only: sequence should be changed or sequence should remain unchanged.
In comparison with other methods of formalization known from other papers [6] some additional assumptions have been adopted. The set of attributes and its realizations has been transformed into the set of values ranging from 0 to 1 in such a way that each attribute realization constitutes a separate raw in the attribute table. For example, if the attribute set-up time can take three values: large, medium or small, then we introduce three rows into the decision table corresponding to each attribute realization. Therefore, the table of input data contains only 0 if a sequence does not include the given attribute or 1 if this attribute is present. An example of the decision table related to technical partial criterion is presented in table 1:

Table 1. An example of the decision table related to technical partial criterion.

<table>
<thead>
<tr>
<th>Technical criterion</th>
<th>Set-up time in operation No 1</th>
<th>Set-up time in operation No 2</th>
<th>Set-up time in operation No 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>long</td>
<td>long</td>
<td>long</td>
</tr>
<tr>
<td></td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td></td>
<td>short</td>
<td>short</td>
<td>short</td>
</tr>
<tr>
<td>Sequence</td>
<td>unfavourable</td>
<td>neutral</td>
<td>favourable</td>
</tr>
</tbody>
</table>

Transformation of the table into the decision tree consists in setting consecutive attributes (rows in the table), which most strongly diversify the set of objects (give a largest amount of information about the set of objects). The appropriate calculation procedures based on estimation of entropy as a measure of information content about objects enables an unique classification of the given sequence (as favourable, unfavourable etc.). Through these procedures we obtain the decision tree which function is to generate the set of production rules forming the optimized knowledge base. With respect to way in which knowledge is used, the only relevant inference mechanism is the backward inference. This imposes a method for transformation of the obtained decision tree into the set of rules. Some examples of such rules are presented below:

IF set-up_time_1 = “long” AND set-up_time_II =”long” AND idle_time_I_II=”long”
THEN ASSIGN “unfavourable” technical_criterion

IF technical_criterion = “unfavourable” AND economic_criterion=”unfavourable” AND commercial_criterion=”favourable”
THEN ASSIGN TRUE change
An example of application of planning system

The presented methodological approach was employed for the construction of a prototype of the calendar planning system at steelworks. In case of rolled products the production planning is applied to a very wide range of products with respect to their shape and size as well as to steel grade being processed. In addition, the production planning is complicated by application of complex and various technological processes (from steel melt and casting up to preparing and preheating charge, rolling, heat treatment and finishing) and by correlation between consecutive links coexisting in the technological process for rolled products. Normally, quantities ordered by customers differs radically from optimal production batch volume at a rolling mill. Change of size or shape requires rolls to be readjusted which leads to rise in production cost and interruption in rolling process. These depend on rolling sequence for particular shapes and sizes of rolled batches between two consecutive roll readjustments.

Simultaneously, the free market conditions cause that criteria for assessment of suppliers become considerably wider. Apart from traditional criteria hitherto considered and exposed, such as price of product, its quality and certificates obtained by manufacturer, also other criteria become more and more important, for example customers' service, time of delivery, promptitude in deliveries, adjustment of delivered batch to customer's requirement.

The problem of calendar planning at steelworks manufacturing the rolled products corresponds to the model outlined in the first part of this paper. We deal with the problem of sequencing production tasks under various constraints and numerous criteria. Among criteria we can list:
- minimizing readjustment time at a rolling mill,
- decreasing number of steel grade changes cast at steelworks,
- keeping liquidity as profitable as possible,
- minimizing a time of performance for orders,
- other parameters (mainly related to the market) which are often difficult to be expressed numerically.

To construct a prototype of the calendar planning system for production at modern steelworks of the most widespread layout (electrical furnaces, continuous casting line, rolling mill) manufacturing products on customers' orders (almost without storing finished products) the authors used the NEXPERT system of the NEURON DATA company [4]. The knowledge base of the system was built as a declarative representation of knowledge about principles of timing.

During construction of the knowledge base following three groups of criteria have been considered:
- technical (set-up time of rolling mill, furnace capacity factor, etc.),
- economical (profitability of rolling mill tasks, time of payment etc.),
- commercial (volume of order, form of payment, customer's priority).

The research task was reduced to defining the knowledge base structure and then to determining inference efficiency on that base. According to the method of knowledge acquisition and defining presented above, the knowledge base structure was determined and described in a form of the set of rules belonging to the NEXPERT
system. Then, efficiency and effectiveness of the method of calendar planning based on the sequencing module with the knowledge base were verified through simulation experiments. Due to variety of partial criteria it was difficult to set an unique criterion function for entire task. An assessment of fluidity in cash resulting from performance of given production time schedule belongs to possible approximations. For this purpose a parameter calculated identically as the NPV factor used for evaluation of investment effectiveness can be applied [8]. Experiments were based on study of the planning system behaviour within a finite period of time for randomly chosen sequences and characteristics of production tasks. The value of the synthetic criterion function was referred to partial optimum obtained by random sampling methods from sample of sequences for each planning step. The obtained results enable us to conclude that the adopted methodology is effective and has many advantages. Among them we can list:

- high effectiveness in comparison to the method consisting in permutative determination of sequences on the base of random samples,
- significant flexibility of the NEXPERT system enabling quick reconstruction of the knowledge base,
- universality of the method allowing application of the system of identical internal structure to solve problems of various characteristic.

At present the research and experimental studies consisting in comparison of results obtained from the planning system with the knowledge base with heuristic methods (based mainly on evolutionary algorithms) are carried out.

References


[7] Stawowy, A., Mazur, Z., Heurystyczne algorytmy szeregowania zadań produkcyjnych i grupowania wyrobów, [w:] Nowoczesne metody zarządzania
PROBLEM DEFINOWANIA WIEDZY DLA POTRZEB SYSTEMÓW ZARZĄDZANIA PRODUKCJĄ

Zarządzanie produkcją wydawało się często zadaniem o stosunkowo prostych regułach określających sposoby i kryteria postępowania. Sądzono, że jednoznacznie określić można ograniczenia i relacje wiązujące zadania produkcyjne z możliwościami technicznymi i technologicznymi a funkcja kryterium, określana jako terminowość realizacji zadań jest także łatwa do sformułowania. Formalizacja i optymalizacja tego zadania zdawała się nie przedstawiać większych problemów analitycznych. W praktyce okazuje się jednak, że wyodrębnienie tak postawionego problemu w postaci czystej nie jest możliwe. Nie wolno rozpatrywać odrębnie zagadnień technicznych, organizacyjnych i logistycznych w oderwaniu od determinujących je ograniczeń i możliwości związanych z takimi sférami zarządzania jak marketing, finanse i zarządzanie zasobami ludzkimi.