

Scheduling of production on the base of linguistic decisive rules

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ABSTRACT: The paper presents application of the fuzzy logic to the multicriterial scheduling and control of production systems. The process of production scheduling involves decisive linguistic rules obtained using simulation examinations. The stage of simulation delivers numerical results, which are treated as learning data. The construction of the rules base applies an algorithm of linguistic rules generation on the basis of numerical data. The quality of rules obtained automatically was assessed by comparison of generated results with the assessment of importance of orders made by an expert.

KEYWORDS: Production planing, fuzzy logic, manufacturing system

1. INTRODUCTION

Modern computerized manufacturing systems increasingly accentuate small batch production with high variability of products. This tendency makes routing and scheduling an intractable problem. In addition to the increased complexity, the time frame in which the solution is needed keeps decreasing. The approach presented in this paper remedies these difficulties by interdicting an efficient real time method for scheduling and controlling of production. Robotized systems use determined algorithm to realize workpiece flow in machining systems using industrial robots. Such algorithm provides appropriate (in accordance with technological process) transport of particular workpieces and determines the way of reaction of transporting system to the appearing during work signals, which determine present state of particular resources of the system. Manufacturing process, which is described by technological itinerary, can execute different algorithms of transport processes control. Selection of the proper algorithm depend on organizational conditions – technological schedule – relative relations of components subsystems (distance between component subsystems, speed of transport movements, times of machining operations, capacity of stand buffers and transporting devices, number of grippers of robots etc.) [1,2].

Algorithms built on the base of conventional rules do not allow to maximize possibilities of modern flexible production systems, especially in unit and small batch production [3]. Therefore robotized systems that perform small batch production of multiple simultaneous orders use single criterion control rarely.

To control production system correctly it is necessary to use multicriteria decisive rules, which consider requirements, connected with necessity of realization of effective production.

It leads to usage of linguistic rules that are based on the expert knowledge. These rules are generalized experience of operator gained during years of professional activity or the results of simulation examination [5].

2. DECISIVE RULES USED FOR SCHEDULING AND CONTROL OF PRODUCTION

Basic elements for controlling production in a robotized machining system are a short-term production plan and a detailed schedule of manufacturing of particular batches of products. To elaborate the detailed schedule, determine start and end of particular production orders it is necessary to use appropriately configured base of decisive rules (Fig. 1).

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Conventional scheduling and control of robotized production systems is realised mostly using heuristic decisive rules of FIFO, LIFO or minT₀ type [2]. Apart of undoubted advantages (simplicity, easy implementation) these rules have common disadvantage, which is stiffness, which disables consideration of specific system properties and its dynamic processes. They do not enable utilisation of operator experience who knows possibilities and limitations of the

controlled system. An effective way to obtain algorithms of industrial robot work control which suit to the present conditions is the method based on simulation examinations using linguistic decisive rules [3]. This method is based on the application of simulation examinations to the assessment of effectiveness of any determined decisive rule before applying it to the system of production process control. Since it is necessary to realize small batch production in the robotized systems with many different orders executed simultaneously, single control criterion is used very rarely. In the modern robotized machining systems control takes into account factors as for example profit of particular orders, financial penalty for not keeping to the deadlines etc. One of the possible solutions is application of linguistic decisive rules and fuzzy reasoning methods (based on the experience and intuition) to the control of production.

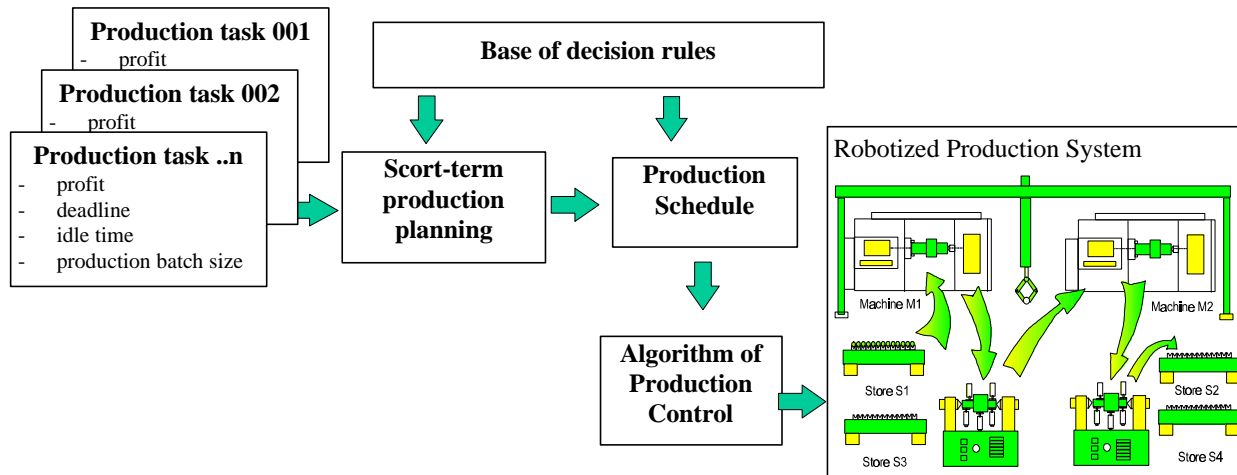


Fig. 1. Course of the control of production process in the robotized machining system

During construction of Fuzzy Logic Controller there are two main problems:

- determination of linguistic values and assigning to them membership functions,
- formulation of the base of linguistic rules of the fuzzy control reasoning.

To overcome the above mentioned problems the method of constructing the base of decisive rules is proposed. It is based on the numerical data obtained during simulation. Application of simulation examinations allows obtaining necessary numerical data, which are results of system model work during manual control. The data collected during simulation examinations reflect the way of reaction of the system operator in the case of making decisions concerning selection of an order on the base of parameters as the order deadline, idle time, batch size and order profit. The stage of simulation examinations, when the numerical database is created, can be called learning mode. After the set of numerical data is prepared, the base of linguistic decisive rules was constructed (Fig.2).

A sample linguistic rule, which applies three parameters (time of order realisation, deadline and order profit) and allows for selection of orders, can have the form:

If **z1 order profit** high
 and the **deadline** very short
 and **idle system time for order Z1** average
 then **importance of order Z1** very great

This example demonstrates that the purpose of the rules is to define a factor called **importance of order**. This factor is used to the selection of orders during construction of the detailed schedule of work of the manufacturing system. The base of decisive rules is made up with a set of such rules, which describe system dependencies. System operator uses these rules to assess production orders and to assign to each order the significance index.

To elaborate effective algorithm of the manufacturing system control usage of linguistic decisive rules and methods of fuzzy reasoning in the form of Fuzzy Logic Controller (FLC) is proposed [8, 9]. Structure of such a system allows to generate control decisions on the base of linguistic rules, which effectiveness is checked using simulation examinations.

In the case of control of the manufacturing system construction of the base using expert knowledge is a difficult task. It is difficult to define linguistic rules, which allow to solve conflicts regarding simultaneous orders. Then it is necessary to decide which order should be accepted as the first in a row and what is the possible time of realisation of this order.

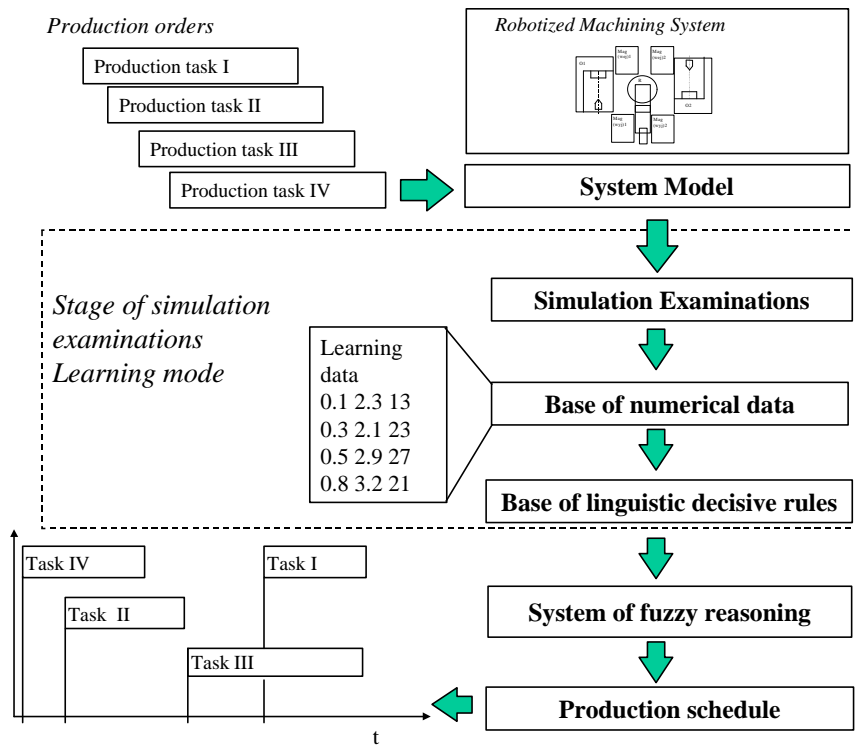


Fig. 2. Scheduling of production on the base of linguistic decisive rules

The algorithm of designing of the linguistic rule base on the basis of numerical data is based on the Fuzzy-Rosa method [4,5]. It considers such elements as searching linguistic space, generalisation of the set of conditions of rules, method of reduction of rules and analysis and automatic assessment of generated rules. First of all, hypotheses in the form of if/then rules are generated. They describe possible dependencies between the input and output variables of the process. Every single hypothesis is checked for relevance and evaluated with a rating index. For computing this rating index we used the statistical test, which describe the relevance of the rule in respect to the learning data. Algorithm of automatic generation of the set of linguistic rules on the basis of learning data is presented in Fig. 3. Learning data necessary for the generation of rules consists of relations sets of the form:

$$[x_1(i) , x_2(i) , \dots x_n(i) ; d (i)] \quad i = 1 , 2 , \dots \quad (1)$$

Where $x_1(i) , x_2(i) , \dots x_n(i)$ are input data, $d(i)$ given value of output variable.

Construction of the base of fuzzy rules was conducted for a manufacturing system for which the set of learning data was obtained from experts. The following input linguistic data were defined:

1. WVz – necessary relative speed of realisation of the order of value from 1 to 10, which exhibits planned term of order completion. High values of WVz are assigned to orders that are necessary to complete in a short time. The influence of this parameter on the importance of an order is typically high.
2. W-num. – coefficient exhibiting the production batch size of value from 1 to 10
3. W-prep. - relative speed of preparation for machining of value from 1 to 10 which describes the working time needed for preparation of machines for the production of the determined production batch.

Importance of the production order was assessed by an expert on the basis of the defined above three input variables in the scale of 0 to 10. Part of the set of numerical data obtained was presented in Fig. 4 (it contains about 100 sets of data). It presents learning database, which consists of three columns corresponding to particular input variables respectively, and the fourth column, which describes the output variable - the importance of the order.

Using WINROSA program (from MIT Aachen), in which algorithm of automatic generation of linguistic rules was implemented, a set of 377 decisive rules was obtained. Because of a small number of input variables the method of systematic searching of the space of possible decisive rules was selected.

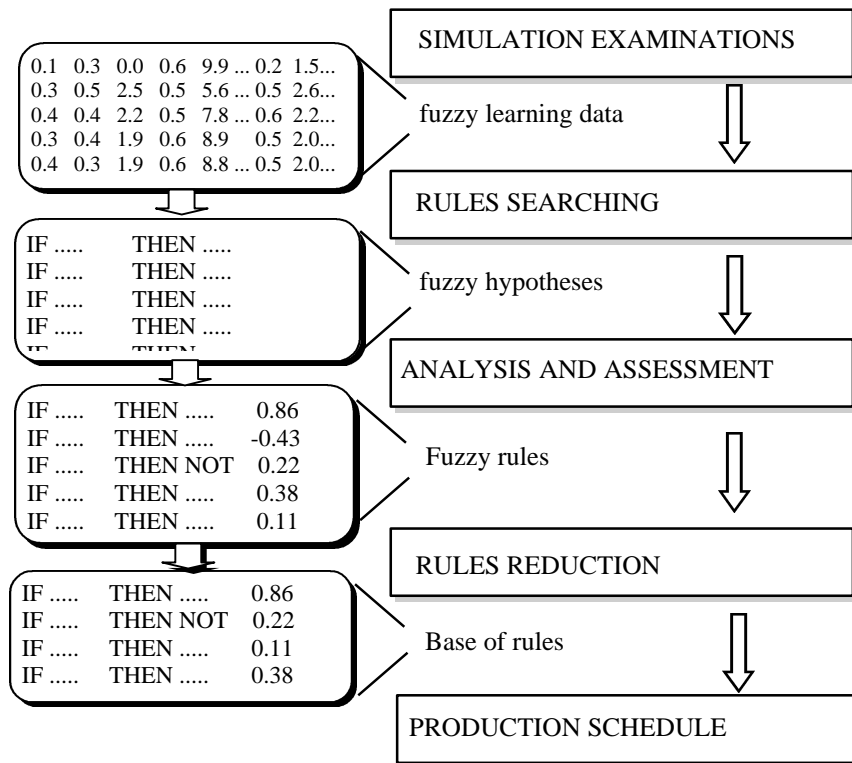


Fig. 3. Algorithm of automatic generation of linguistic rules

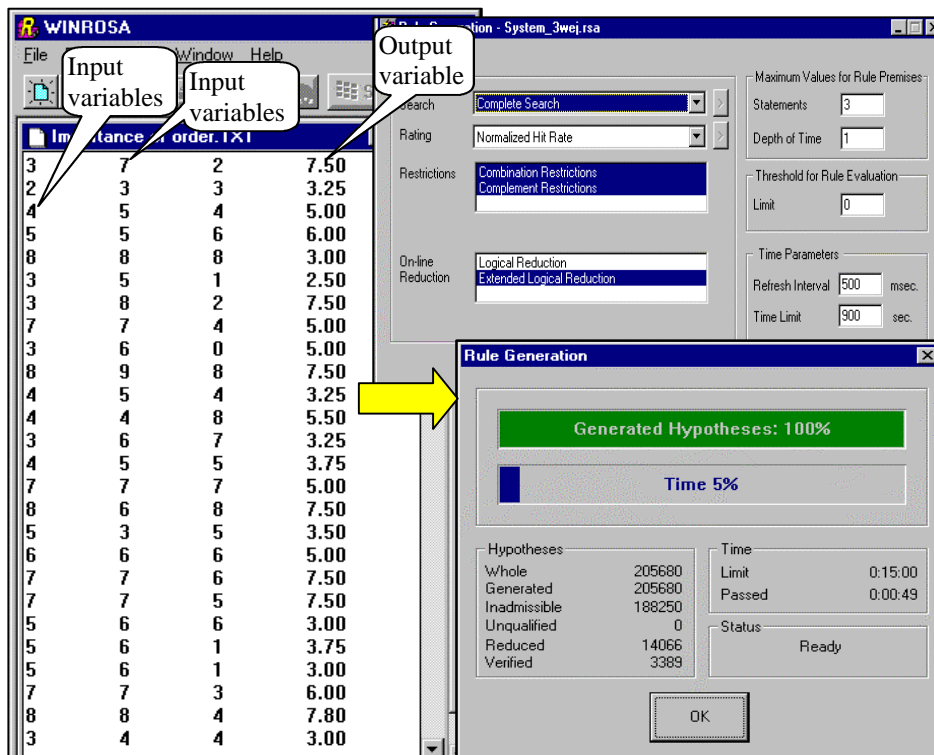


Fig. 4. Learning data for assessment of the significance of production orders

Because of existence of high number of rules of low degree of reliability, their reduction was conducted. Rules having the index lower than 0.5 were cancelled. Rules being in conflicts within the structure of numerical database and connected with possible output situations were also rejected. In result 183 linguistic rules were obtained. Sample rules are presented in Tab. 1.

rule1	if (necessary relative speed = high And production batch size = small) then importance of order = low
rule2	if (necessary relative speed = v. low And production batch size = v. small) then importance of order = average
rule3	if (necessary relative speed = v. low And production batch size = average) then importance of order = v. little
rule4	if (necessary relative speed = v. low And production batch size = v. small) then importance of order = average
rule5	if (necessary relative speed = b low And production batch size = average) then importance of order = v. little
rule6	if (necessary relative speed = v. low) then importance of order = great
rule7	if (necessary relative speed = low And production batch size = v. small) then importance of order = average
rule8	if (necessary relative speed = low And production batch size = small And relative speed of preparation = high) then importance of order = little
rule9	if (necessary relative speed = low And production batch size = average And relative speed of preparation = high) then importance of order = v. great

Tab. 1. Sample linguistic rules obtained on the basis of numerical data

3. ASSESSMENT OF THE IMPORTANCE OF PRODUCTION ORDERS

Using generated linguistic decisive rules a system of fuzzy reasoning was built. It allows assessment of importance of the particular production orders. This system was built on the basis of the computer program DataEngine (from MIT Aachen) that is used for modelling of Fuzzy-Logic systems. A series of sample numerical experiments that included verification of the correctness of the membership functions, selection of fuzzy inference system and the way of defuzzification was conducted. The view of a computer screen during examinations is shown in Fig. 5.

Correctness of generated rules was evaluated comparing the calculated indexes of importance of particular orders with the expert evaluation. Evaluation of the degree of correctness of generated rules was based on the same set of orders that were used for the base construction. The comparison is presented in Fig. 6. One can notice good conformity of both assessments (correlation is about 85 %). Existing differences concern cases in which expert's assessment was based on undefined factors.

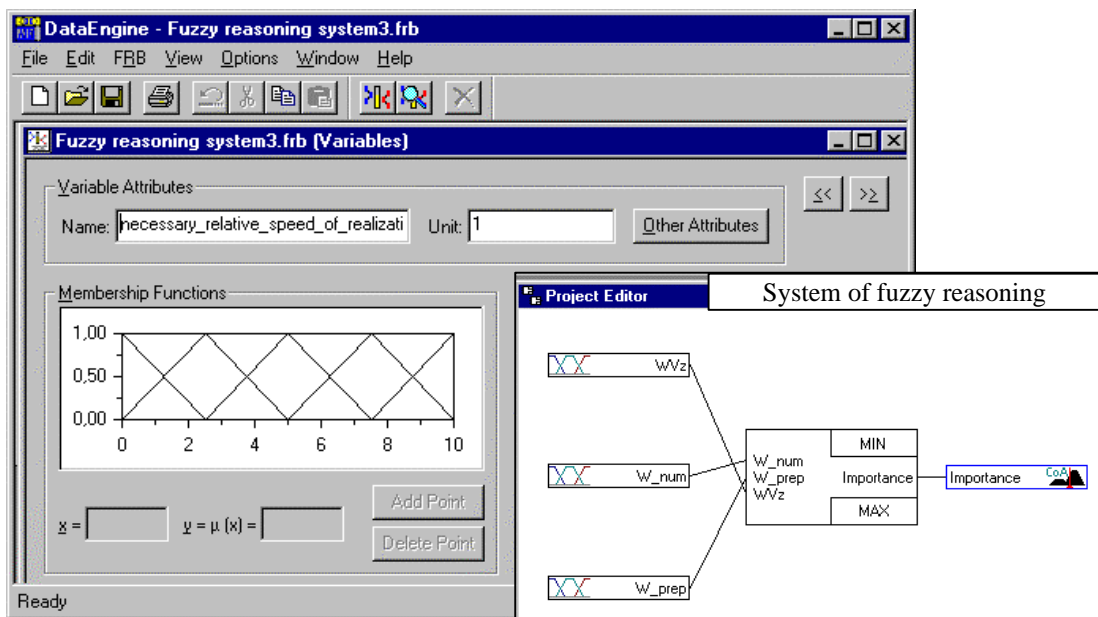


Fig. 5. Fuzzy reasoning system which controls selection of the production orders

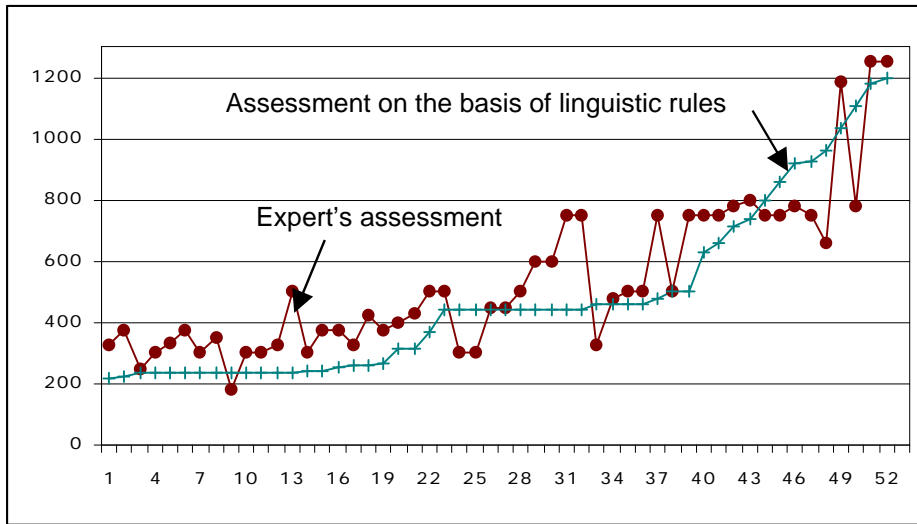


Fig 6. Comparison of expert's and computed degrees of orders importance

Tab. 2 presents example parameters of evaluation of some production orders including assigned to them by the expert and computed degrees of importance by the system. Preliminary analysis of the data concerning 70 orders that are presented in Tab. 2 indicates general accordance of assessment corresponding to the general trend when increase of parameters is accompanied by the increase of order degree of importance. For the case of the highest values of input parameters, orders 69 and 70 were marked 917 and 1250, correspondingly.

Order number	Parameters			Expert assessment	Fuzzy-Logic system assessment
	Relative speed of realisation WVz	Relative batch size W num	Relative speed of preparation W prep		
1	2	3	3	325	220
5	2	6	6	330	233
.
.
3	3	5	1	250	233
40	3	7	2	750	628
51	3	7	9	1250	1182
.
.
26	7	7	5	750	444
37	7	7	6	750	475
38	7	7	7	700	501
43	7	7	8	800	738
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42	8	8	4	780	713
46	8	8	9	780	917
49	10	10	10	1250	1051

Tab. 2. Comparison of sample assessment of an expert and the Fuzzy-Logic system

However, the analysis of some of expert decisions indicates significant differences at the similar values of input parameters. For the case of order No. 32 the expert assigned much higher importance (1250) than for similar orders Nos. 30 and 31. Order 58 has lower degree of importance (700) than order 57 (750), though input parameters of order 58 are higher than those of order 57.

Such unjustified assessments of orders, from the mathematical point of view, present “noise” in measurement data taken from the modelled object. It makes difficult generation of proper linguistic rules.

However, the “noise” presented in the assessment process can be apparent only. Psychological examinations indicate significant influence of human’s subconsciousness and intuition in the decision making process. Intuition reflects knowledge gained by a man in the past. Intuition of an expert, who controls the production system, is collected during years of practice. It impacts his decisions. In fact, the decision is based not only on the three assumed input parameters but as well on observations, also those not defined as inputs.

4. CONCLUSIONS

This article presents an application of intelligent techniques to the area of production planning. Application of Fuzzy-Logic systems for controlling of orders in machining systems allows for the consideration of multicriterial decisive rules. The basic problem in construction of such systems is to get the correct system of linguistic rules from the system operators. These rules are in most cases well formulated and applied. The author proposes to build such a base with the help of numerical data gathered during simulation examinations. The algorithm of construction of the linguistic rules base allows for the consideration of the reaction of the expert to input parameters. This enable obtaining linguistic rules, which suit actual conditions of the system work.

The author plans to generalise some results of comparison between the base of linguistic rules generated automatically with the rules obtained directly from an expert. This should help to solve the problem of automatic correction of generated rules.

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