Multiagent Approach Application for Scheduling of Production Processes

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Abstract[1]

An automated scheduling of production process is used very often to improve the effectiveness of the company, but some questions of intradepartmental planning remain unsolved. This article discusses issues related to scheduling of the production process. The analysis of information systems for solving of such class of problems is carried out. It is suggested to develop software to increase the effectiveness of the company which allows to take into account the specific features of the production process – the productivity of workers, equipment and quality of execution. A mathematical model for scheduling is constructed. A multiagent approach is suggested to implementing the software.

1. Introduction

Efficient work of the enterprise depends primarily on the quality of production scheduling, resource allocation, balanced load of production facilities by produced details. Making an activity network of details movements manually with large volumes of information is almost impossible or very labor-consuming and the results are often inaccurate. It is needed to make such activity network of details movements and load of production facilities in order to minimize the cycle time of manufacturing of details by distributing of work between the workers, choosing of available equipment and resources to carry out these works.

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To solve these problems there are a number of software tools - MES-systems [1, 2]. But despite of variety of them, the problems of resource management and manufacturing production coordination are solved incompletely. The planning is fast, all changes are made immediately, information about workload, manufacturing output is displayed visually in the charts. However, the individual characteristics of workers and equipment are not taken into account when scheduling, but these factors are extremely important. The entire staff having the same profession looks as if they are interchangeable machines – robots. It is considered that there are no changes if the replacement of one of them with another is happened. But in reality, people are working at different speeds, quality and even have their own preferences in the work, which usually have a strong effect on the schedule. The equipment can also have restrictions on size, weight of details, manufacturing quality products, etc.

2. Problem definition

Let's consider the scheduling problem of the production shop. It is necessary to make several different types of details to perform the nomenclature shop plan. Technological process of manufacturing of each detail implies the implementation of a number of technological operations.

There are various resources (personnel, tools, equipment) required for executing manufacturing operations to produce details. Resources are divided into categories: milling machine, turner, milling, lathes, tools. A resource can belong to several categories (mainly the staff has such universality), for example, a turner can do the work of milling. To perform technological operation the resources of various categories are required.

The details may have different properties, such as: weight, length, width, height, material, hardness, and so on. These properties can affect the speed of the operation and manufacture of details in general.

The specificity domain imposes restrictions on the performance of manufacturing operations. Suppose that a certain detail has a mass of 300 kilograms, and the resource lathe has a maximum carrying capacity equal to 250 kilograms. Then that lathe can not machine the detail. Or, for example, milling-machine operator can not work with copper (human factor), and it is necessary to produce the detail from copper (property of the material = copper). Therefore, this operation is better to appoint another worker with skills in copper processing.

3. Formalization of problem

The system has three elements:

- detail – it is the object which is produced (final product);
- operation – these are the actions that must be done to produce a detail or perform one step of a detail processing cycle;
- resource – these are workers, equipment, tools and so on - all that is necessary for technological operations to produce a detail.

Suppose there are N details and M resources. To produce every detail it is necessary to perform a number of technological operations

E_i – number of operations needed to produce i-th detail.

Every detail has properties such as size, material, hardness, etc. The resources may have constraints with respect to these properties. That can influence the manufacturing process.

Resources have properties such as productivity and quality, which influence the manufacturing process also.

D – set of details, $|D| = N$;

O – set of operations, $|O| = E$;

O_i – set of operations needed to manufacture detail i.

$|O_i| = E_i$, $O_i \subset O$;

R – set of resources, $|R| = M$;

R_{ij} – set of resources, necessary to perform the operation j for the manufacture of detail i, $|R_{ij}| = M_{ij}$;

P – set of properties, $|P| = W$;

S_r – value of property "productivity" of resource r – numerical value [0,5; 2,0];

MR – matrix specify the number of required resources;

MR_{ijK} – number of resources of category K, necessary to perform the operation j for the manufacture of detail i.

MX – matrix of resources assignments

$$MX_{ijr} = \begin{cases} 1, \text{ if operation } j \text{ uses resource } r \\ \quad \text{for production of detail } i; \\ 0, \text{ otherwise} \end{cases}$$

MPD – matrix of properties details

$$MPD_{pi} = \begin{cases} \text{value of property } p \text{ of detail } i; \\ \text{NULL} - \text{not use} \end{cases}$$

Example. Suppose that coppery detail has mass 300 kilograms. It means that detail D_i has properties: "material" and "mass", and theirs values are "cooper" and 300 accordingly.

MPR – matrix of limitation resources on attitude to properties details, where

MPR_{pr} – type limitation resource r on attitude to properties p;

Example. Carrying capacity lathe is 250 kilograms and it is impossible to machine the details with bigger mass on it. That is lathe have constraint on property "mass" of detail. Milling-machine operator can not work with copper, that is milling-machine operator have constraint on detail property "material".

Operation is described with two indexes:

i – number of detail;

j – number of operation of detail i according to detail production technology.

Let:

T_{ijm}^{B} – moment of starting of operation j for detail i production by set of resources m;

T_{ijm}^{E} – moment of ending of operation j for detail i production by set of resources m;

L_{ij} – normative time of operation j execution for detail i;

Then total duration of detail i production is defined by the formula:

$$L_i = \sum_{j=1}^{E_i} L_{ij}, \tag{1}$$

where E_i – number of operations, which is necessary for production of detail i.

Coefficients of productivity have effect to speed production of detail. Therefore formula (1) will be the following:

$$L_i = \sum_{j=1}^{E_i} \left(\frac{L_{ij}}{f(MX, S, i, j)} \right), \tag{2}$$

where $f(MX, S, i, j)$ – function which take into account the productivity of used resources for executing of operation j for detail i production.

Introduce restrictions.

1. Number of resources used during the operation j for manufacture detail i should be equal to the sum of the quantities of the necessary resources required for all categories:

$$\sum_{r \in R_K} MX_{ijr} = MR_{ijK}, \qquad (3)$$

where R_K – set of resources from category K used for operation j of detail i production.

2. Qualification of the resource should not be lower complexity of its work:

$$Q_r \geq QR_r, \qquad (4)$$

where Q_r – value of property "qualification" of resource r – number value [1; 10];

QR_r – value of property "complexity works" of operation r – number value [1; 10].

3. Performing of operations is sequentially for every detail, so there are time costs not related to manufacturing-execution operations:

$L_{ij}^{PBefore}$ – amount of idle time before starting operation j for manufacture of detail i connected with preoperative adjustment.

L_{ij}^{PAfter} – amount of idle time after finishing operation j for manufacture of detail i connected with postoperative readjustment.

Then formula (2) will be:

$$L_i = \sum_{j=1}^{E_i} \left(\frac{\left(L_{ij} + L_{ij}^{PBefore} + L_{ij}^{PAfter} \right)}{f(MX, S, i, j)} \right) \qquad (5)$$

4. One resource can not be used simultaneously in more than one operation during production, i.e. a resource r is used by operation i_1 or operation i_2:

$$\begin{cases} T_{i_x j_1 r}^{B} - T_{i_y j_2 r}^{B} \geq \dfrac{\left(L_{i_y j_2} + L_{i_y j_2}^{PBefore} + L_{i_y j_2}^{PAfter} \right)}{f(MX, S, i, j)} \\ \text{или} \\ T_{i_y j_2 r}^{H} - T_{i_x j_1 r}^{H} \geq \dfrac{\left(L_{i_x j_1} + L_{i_x j_1}^{PBefore} + L_{i_x j_1}^{PAfter} \right)}{f(MX, S, i, j)} \end{cases}, \qquad (6)$$

where $j_1, j_2 \in O$, $i_x, i_y \in D$.

In the first case the operation j_2 started before the operation j_1, and the operation j_1 waits until operation j_2 will end. In the second case – on the contrary.

Under resources limitation introduce $L_{ijR_{ij}}^{PW}$ – amount of idle time is not associated with preoperative and postoperative readjustment, reconfiguring (the duration of resource waiting). $L_{i_y j_2 R_{i_y j_2}}^{PW}$ – amount of idle time of operation j_2 detail i_y related with waiting set of resources $R_{i_y j_2}$ is calculated as difference between ending time postoperative readjustment of operation j_1 detail i_x and beginning time of preoperative readjustment of operation j_2 detail i_y, which use the same resource.

Thus the formula (5) will be the following:

$$L_i = \sum_{j=1}^{E_i} \left(\frac{\left(L_{ij} + L_{ij}^{PBefore} + L_{ij}^{PAfter} \right)}{f(MX, S, i, j)} + L_{ij}^{PW} \right) \qquad (7)$$

Then finishing time of production detail i.

$$T_i^E = T_i^B + L_i, \qquad (8)$$

where T_i^B – moment of beginning production of detail i.

Operations of different details manufacturing by different resources can be performed independently from each other.

Then the finishing time of all operations performance will be:

$$T^E = \max_i \left(T_i^E \right) \qquad (9)$$

Starting time of operations performing:

$$T^B = \min_i \left(T_i^B \right) \qquad (10)$$

Then the total time of all operations performing:

$$L = T^E - T^B \qquad (11)$$

Substituting in formula (11) formulas (10), (9), (8), (7), find:

$$L = \max_i \left(T_i^B + \sum_{j=1}^{E_i} \left(\frac{\left(L_{ij} + L_{ij}^{PBefore} + L_{ij}^{PAfter} \right)}{f(MX, S, i, j)} + L_{ij}^{PW} \right) \right) - \min_i \left(T_i^B \right) \qquad (12)$$

It is required to minimize the total duration of all details production

$$\left(\max_i \left(T_{ijm_j}^B + \sum_{j=1}^{E_i} \left(\frac{\left(L_{ij} + L_{ij}^{PBefore} + L_{ij}^{PAfter} \right)}{f(MX, S, i, j)} + L_{ij}^{PW} \right) \right) - \min_i \left(T_{ijm_j}^B \right) \right) \rightarrow \min \qquad (13)$$

Since the production of details begins with first operation, then:

$$\max_i\left(\mathrm{T}^{B}_{i1m_1}+\sum_{j=1}^{E_i}\left(\frac{\left(L_{ij}+L^{PBefore}_{ij}+L^{PAfter}_{ij}\right)}{f(MX,S,i,j)}+L^{PW}_{ij}\right)\right)-\min_i\left(\mathrm{T}^{B}_{i1m_1}\right)\rightarrow\min \quad (14)$$

Thus, the task of output of products accelerating is to reduce the total time of manufacture L. This can be achieved by minimizing the time of manufacture (the selection of resources with a high coefficient of productivity), and reducing the resources waiting time.

3. Suggested approach to solve the problem

It is suggested to use multiagent approach for software development to solve the problem.

Agents are active objects (software modules) [3, 4], that can initiate a purposeful activity in the perception of the environment and the impact on it, with the following "mental" properties (or a subset):

- knowledge – constant, unalterable when in use functioning knowledge agent about himself, environment and others agents;
- beliefs – knowledge's agent about environment (including other agents), which can change in time and become incorrect;
- desires – states, which agent desires to reach (can be conflicting), analogous of purposes;
- commitments – problems, which agent tries to solve by itself in the cooperation with others agents on their request or the instructions;
- intentions – the deliberative state of the agent - what the agent has chosen to do. Intentions are desires to which the agent has to some extent committed.

Multi-agent system (MAS) are self-organizing systems. The main advantage of MAS is flexibility. Multiagent system can be supplemented and modified without rewriting large parts of the program. Also, these systems have the ability to renew itself and resistant to failure due to sufficient supply of components and self-organization.

This method supports the implementation of strategies at the level of "human" heuristics. One can implement an algorithm simulating the behavior of people in this living situation.

In considered problem of scheduling it is suggested to use the following types of agents:

- agent "detail" is object which is produced;
- agent "operation" – these are the actions that must be done to produce a detail or perform one step of a detail processing cycle;
- agent "resource" – these are workers, equipment, tools and so on - all that is necessary for technological operations to produce a detail..

Let's consider possible models of behaviour of these agents.

Agent **"detail"** is an active element of the system, its production is given by a sequence of operations. Basically, this sequence is defined clearly, but it happens that between some of the operations execution order is not important. Agent "detail" executed the first agent "operation". Following the announcement last agent "operation" of its execution, an agent of "detail" remembers the end time of production. In the case of failing in terms of performance of the agent "detail" analyzes the manufacturing to determine when the critical delay and its causes. After identifying the reasons for the delay (if any), the agent "detail" is trying to remedy the situation through "negotiations" with other agents "detail". Flowchart of algorithm of agent "detail" behaviour is presented in fig. 1.

Agent **"operation"** is an active element of the system. It needs in resources to perform. Agent "operation" receives a command to find the necessary resources. To do so, it polls all categories of resources, it requires the presence of free time during its execution. Agent "operation" finds the necessary resources, this takes into account the various properties details. Depending on the value of property "productivity" agent "operation" corrects the end time fulfillment and gives the command to the next agent "operation" to implement, passing the data on the end of execution. This continues to fulfill the latter agent "operation" in the sequence of processing. After the last agent "operation" is executed, he tells the agent "detail" about the end of processing.

Agent **"resource"** is a passive element of the system. Its mission is to monitor what operation and when use it. Flowchart of algorithm of agent "detail" behaviour is presented in fig. 2.

4. Conclusion

The problem of scheduling of production processes is considered on the example of forming a plan of manufacturing of details. To solve this problem it is proposed multiagent approach. The classes of agents needed to solve the problem are constructed, the algorithms for their behaviour are developed.

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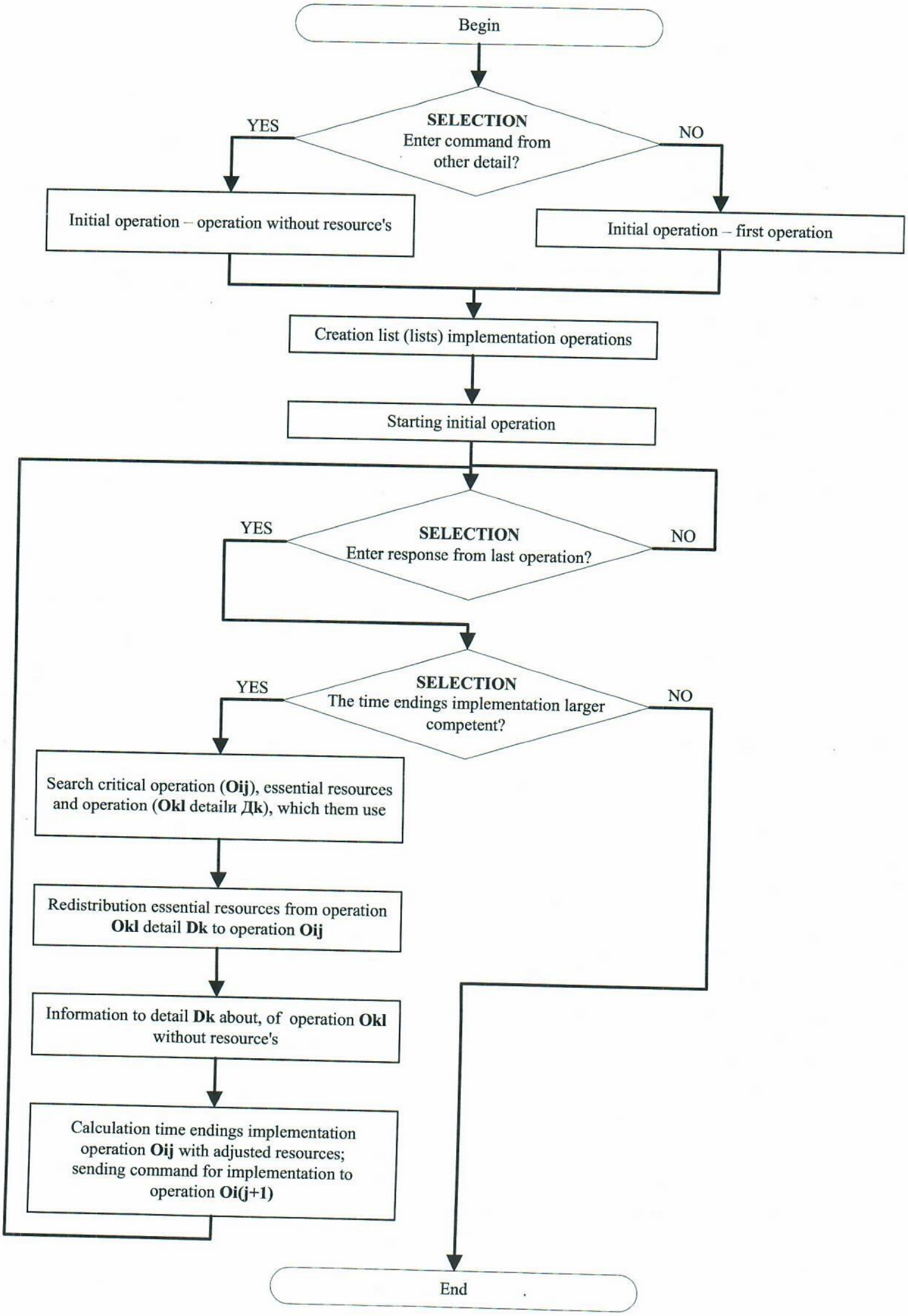

Fig 1. Flowchart of algorithm of agent "detail" behavior

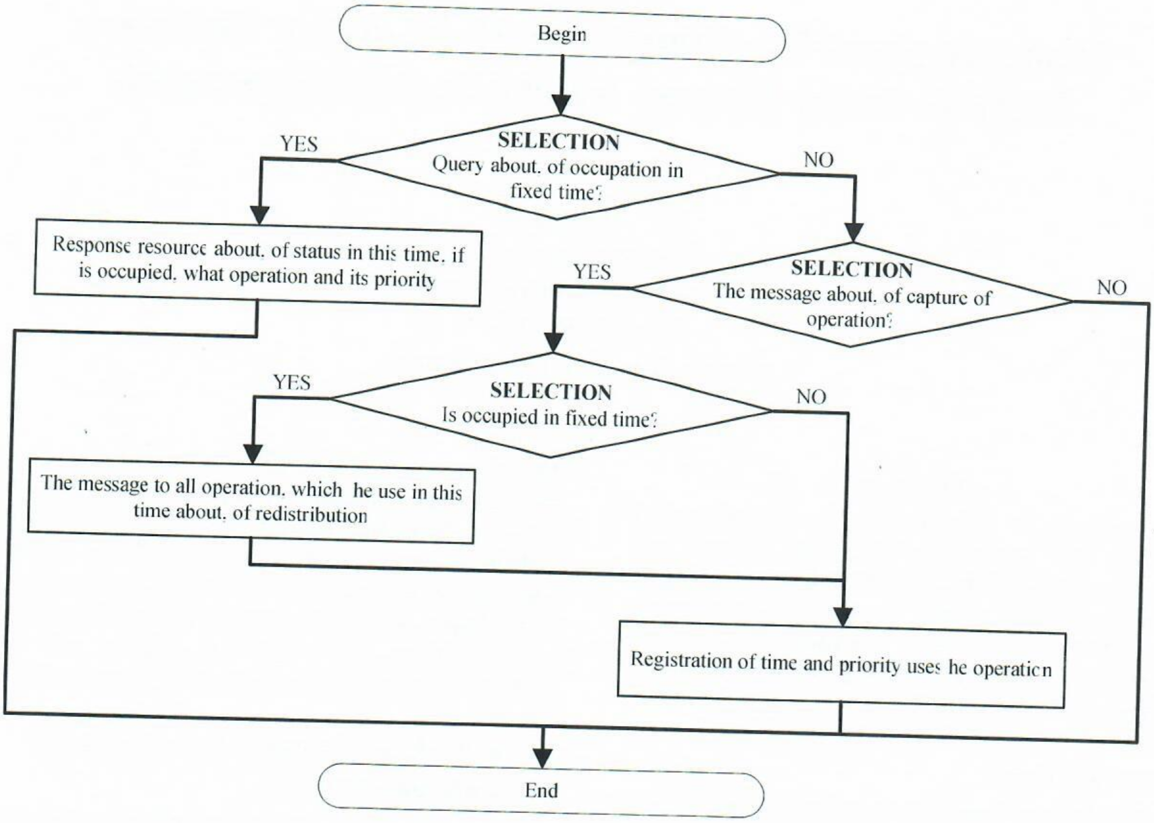

Fig 2. Flowchart of algorithm of agent "resource" behavior

References

1. Frolov E. B., Zagidullin R. R. "MES-systems. MES-systems, what they eat or evolution systems planning manufacture". Part I, Part II, [Electronic resource]: (http://erpnews.ru/doc2592.html, http://erpnews.ru/doc2593.html).
2. Free encyclopedia Wikipedia, [Electronic resource]: (http://ru.wikipedia.org/wiki/MES).
3. Tarasov V. B. From multiagent systems to intellectual organizations: philosophy, psychology, information science. M.: Editorial URSS, 2002. 352 p.
4. Rizvanov D. A., Popov D. V., Bogdanova D. R. Application of distributed artificial intelligence technologies for scheduling problems solving. In: *Proc. of the XIII Baikal All-Russian Workshop on Information and Mathematical Technologies in Science and Management*. Irkutsk, Russia, 2008, Vol. 2, pp.76–82.