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AN ALGORITHM OF SHARED INDUSTRIAL ROBOT CONTROL FOR FLEXIBLE MANUFACTURING SYSTEM

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Summary. A mathematical model of the process of a flexible manufacturing system functioning has been offered. On the basis of the dynamic programming method an algorithm of shared industrial robot control of a flexible manufacturing system has been worked out. Fig.2, ref.4.

Key words: transport system, technological workstation, algorithm optimal, flexible manufacturing system, mathematical modeling, dynamic programming, industrial robot.

INTRODUCTION

Flexible manufacturing systems (FMS) is defined as an integrated computer-controlled configuration of semi-independent workstations and a material handling system, designed to manufacture several part types at low to medium volumes. FMSs are the prime components in the so-called fully automated "factory of the future." FMSs, which are capital-intensive, have high productivity as the primary objective and require quick return on investment and reduced pay-back periods. This is achieved by integrating principles of group technology, just-in-time, manufacturing resources planning II, and total quality control into the design and operation of these systems. FMSs offer several advantages, main of them being improved system utilization, low response time, low work-inprocess, improved quality, reduced labor cost, flexibility in production, and so on. Availability of the various subsystems and of the system as a whole is a prerequisite for achieving both integration and high throughput.

Loading problems in flexible manufacturing systems involve assigning operations for selected part types and their associated tools to machines or machine groups. One of the objectives might be to maximize the expected production rate (throughput) of the system. Because of the difficulty in dealing with this objective directly, a commonly used surrogate objective is the closeness of the actual workload allocation to the continuous workload allocation that maximizes throughput. We test several measures of closeness and discuss correlations between these measures and throughput. Using the best measure, we show how to modify an existing branch and bound algorithm which was developed for the case of equal target workloads for all machine groups to accommodate unequal target workloads. We also develop a new branch and bound algorithm which can be used for both types of problems. The efficiency of the algorithm in finding optimal solutions is achieved through the application of better branching rules and improved dominance results. Computational results on randomly generated test problems indicate that the new algorithm performs well.

In the increasing competitive world of advanced flexible manufacturing, online process control requirements are becoming ever more demanding in terms of fast processing power and high accuracy. Organization of transport system operation determines mainly the efficiency of a flexible manufacturing system functioning. Productivity of separate technological workstation differs essentially. Quite often a sole shared industrial robot maintains several units of technological equipment. In these conditions the decision of the problem of transport system control of a manufacturing complex is particularly difficult. The selected variant of shared industrial robot control must meet many requirements. In this paper we consider problems of the search of an algorithm optimal to the given criterion of shared industrial robot control.

The goal of the present paper is to develop the mathematical model of a flexible manufacturing system functioning process and to build an algorithm of shared industrial robot control of a flexible production complex on its basis. In this work the criterion of quality estimation of shared industrial robot control is offered.

ANALYSIS OF PUBLICATION

Numerous works [Gavrish 1984, Yegorov 1989, Klausov 1990] are concentrated on the consideration of mathematical modelling problems of multifunctional manufacturing system. In the source [Gavrish 1984] the problems of transport line structures analysis in flexible manufacturing systems have been investigated. Analytical models based on the assumption of flowing processes being stationary are offered in the majority of works. However actual manufacturing conditions are influenced by numerous disturbance factors. Under these conditions the assumption of stationary processes makes the received models distantly correspond to the facts.

ALGORITHM DEVELOPING

While working out technological structures of manufacturing systems a variant with one shared industrial robot maintaining several technological modules is often used (Fig. 1). Under inefficient organization of shared industrial robot operation the enforced idleness of technological modules is possible because of the lack of blanks and frequent shared industrial robot readjustments. It is necessary to organize shared industrial robot operation in these systems in such a way that it will not allow or reduce to minimum technological modules enforced idleness and frequent readjustments of the industrial robot.

Analysis of the task of rational strategy search of shared industrial robot control shows that this task relates to dynamic tasks of discrete optimization [Rikhter 1985].

In order to formulate the task of strategy search of shared industrial robot control in terms of dynamic programming we interpolate a series of assumptions. We assume that the average time of transporting is the same for all technological sites and makes t units of time. A shared industrial robot adjustment duration for maintaining a technological module i- is equal to T_H^i units to time. Let us designate by t_H^i a value that shows how many times T_H^i is as large as t. Let us assume that t_i is a value showing how many times the average cycle duration of technological module is as large as t. We designate by E_i a unit capacity of input storage of i module (i =1,M, M – is the number of technological modules, which are maintained by a industrial robot).

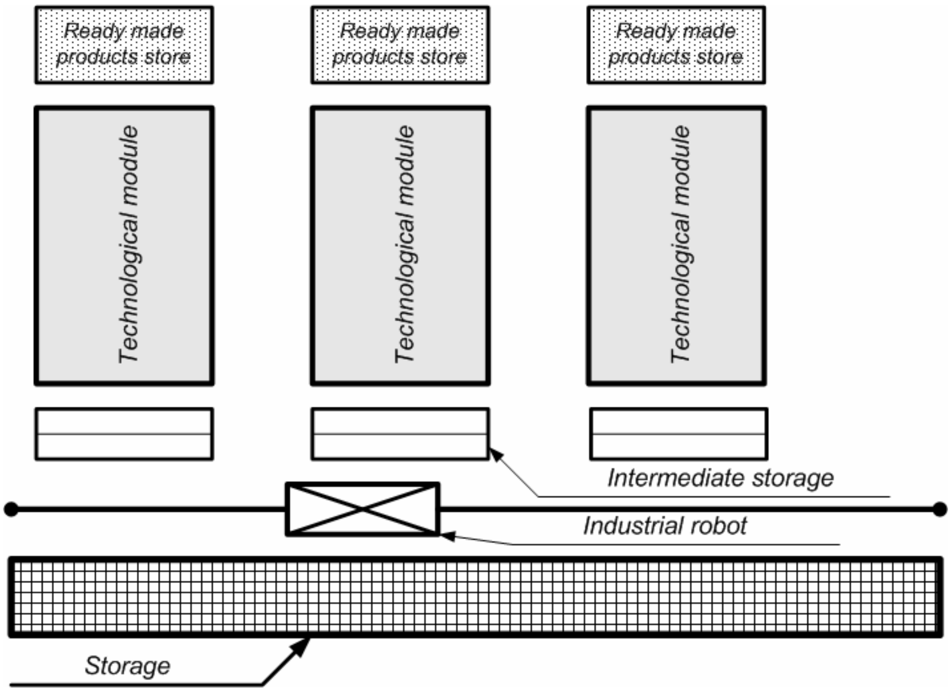

Fig. 1. Scheme of flexible manufacturing system with industrial robot

Let us consider the process of a flexible manufacturing system functioning within the time interval from 0 to T and divide it up into a number of segments Δt. The duration of each segment treats as equal to the duration of transport operation.

Shared industrial robot control will be given in the form of X vector, the size of which equals to the number of K segments, constituting the interval 0..T under consideration. Elements X_j j=1,K of this vector reflect a certain decision taken about shared industrial robot control in the corresponding segment Δt. Let us assume that Xj, has a value l , it means that one of possible decision on a shared industrial robot control has been taken in segment j.

$1 \le l \le M$ - means transporting one paper (product) in segment j to the site 1;

$(M+1) \le l \le 2 \cdot M$ - enforced idleness of a shared industrial robot adjusted to transport products for (*l*-M) technological module;

$(2 \cdot M + 1 \le l \le 3 \cdot M$ - is a readjustment of a shared industrial robot for transporting products to (*l*-2M) technological module.

The space of conditions, which the system under consideration can reach at every step is described by the three <A,B,C>. In this case A is the number of technological module for which a vehicle transporting products is adjusted ($1 \le A \le M$). B and C are vectors of measurement M. Each component b_i (I=1,M) of vector B is equal in number to the quantity of products which are in the input store of *I* site ($0 \le b_i \le E_i$). The component c_i (i=1,M) of C vector shows how many steps (segments) are left for giving a signal by i technological module about readiness to accept the next product ($0 \le c_i \le t_i$). The general number of possible conditions of the system at each step is defined by the expression:

$$M \cdot \prod_{i=1}^{M}((E_i+1)\cdot(t_i+1)), \tag{1}$$

General production cost F, connected with the utilization of the flexible manufacturing system can be written down in the form of a sum:

$$F = F_1 + F_2, \tag{2}$$

Where: F_1 means losses, defined by technological module enforced idleness:

$$F_1 = \sum_{i=1}^{M} e_i \sum_{j=1}^{k} q_{ij}, \tag{3}$$

where: $q_{ij}=1$, if $b_i^j + c_i^j = 0$,

0, otherwise,

e_i – means production costs related to enforced idleness of a technological module i in the terms of one segment Δt.

F_2 means losses related to readjustment of a industrial robot:

$$F_2 = e_p \sum_{j=1}^{k} r_j, \tag{4}$$

where: r_j – 1, if $x_j \le 2M$ и $x_{j+1} > 2M$,

0 - in the other case.

In multistage processes of taking successive decisions a system transition from stage to stage and from state to state is described by a functional equation. For the task under consideration a functional equation of dynamic programming is written down as follows:

$$F_k(s) = \min_{\substack{s \in S \\ s' \in S}} [g_k(s) + F_{k-l}(s')], \qquad (5)$$

where: $F_k(s)$ – is a value of purposeful function (2), received at optimization step K for the condition S,

$g_k(s)$ – is increment of purposeful function under transition of manufacturing system from the state s' at the step (k-l) into the state s at к step,

S' – is the multitude of states at (k-l) step, where transition into S state at k step is possible,

S – is the multitude of possible states of manufacturing system at every step.

L – $t_н^i$, if in the state s of manufacturing system the transition is realized by readjustment of a shared industrial robot for products transporting to technological module i ,

1 в in the other case.

In the Fig. 2 the scheme of operation of the obtained method of shared industrial robot control algorithm synthesis of a flexible manufacturing complex is shown.

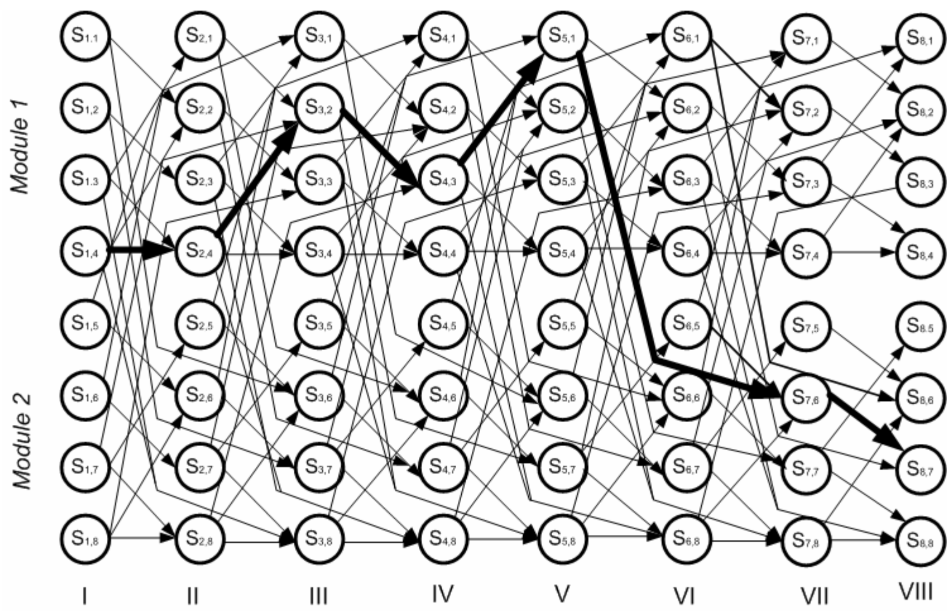

Fig. 2. Operation scheme of the dynamic programming algorithm for strategy search of shared industrial robot control

CONCLUSIONS

Calculation tests with the computer's realization of the received algorithm of shared industrial robot control have shown that it reduces losses related to the utilization of flexible manufacturing system by 25-20%. It should be specially noticed, that the algorithm developed is of highly prompt action. It allows to use it in manufacturing systems where production tasks are frequently changed.

Industrial robots are good examples of flexible manufacturing systems. Using robots in actual manufacturing platforms is, therefore, a decision for flexibility and a way to increase the agility of the manufacturing process. If the manufacturing processes are complex, with low cycle time and have a lot of parameterization owing to the diversity of products, then using robots is the correct decision, although it isn't enough for a complete solution.

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АЛГОРИТМ УПРАВЛЕНИЯ ОБЩИМ ПРОМЫШЛЕННЫМ РОБОТОМ В ГИБКОЙ ПРОИЗВОДСТВЕННОЙ СИСТЕМЕ

Стоянченко С., Швецова Д.

Аннотация. Предложена математическая модель процесса функционирования гибких производственных систем. На основе метода динамического программирования разработан алгоритм управления общим промышленным роботом в гибкой производственной системе. Рис.2, ист.4

Ключевые слова: транспортная система, технологическая рабочая машина, алгоритм оптимального управления, гибкая производственная система, математическое моделирование, динамическое программирование, промышленный робот.