Scientific bases of method of synthesis for the structure of machines that provide packing process by foodstuffs

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Abstract

Introduction. On condition of optimization of process of packeting rationally to use the synthesis of structure of packing machine combinatorics-logical methods.

Materials and methods. A process for sorting and search of new combinations are used for generuting of structures in the array of analogues and prototypes. For this aim it is possible to choose the next methods of description of the generalized structures for packing machines : tabular, algebraic, logical and network models.

Results and discussion. The oriented multigraph is used for the synthesis of structure of packing machines, and also for optimization of separate decisions. The system of limitations and целивые function is generalized for this purpose.The system of limitations is confirmed, and gives an opportunity to describe data of choice of elements for a multicount model, and objective function. It allows to optimize different structural descriptions for decisions. The decision of task of structural synthesis consists of the oriented arcs of multigraph. During the use of this method one class of of packing machines can be presented as oriented multigraph.

In such multigraph great number of multiarcs and it Z={Zi}, i= $\overline{1,n}$ and great number of tops – S={Si}. An arc will be activated on condition of activating of all her exits. The common amount of variables in similar models is described by means of expression 3n+K+M, and an amount of equalizations and inequalities is in the system of limitations - 7n+K+L+1, for n – common amount of elements of the incorporated structure for a packing machine, K – amount of incoming connections; L – amount of the forbidden combinations.

Conclusion. A problem of structural synthesis is brought to the tasks of the discrete linear programming. The system of limitations, that is described in a task, can define the stages for the choice of elements of multicount model, and objective function. It gives an opportunity to optimize different structural descriptions of decisions.

Introduction

A modern packing equipment is the difficult technical system. A basic function for the system is implementation of basic operations, auxiliary operations and additional operations in the process of packing [1].

Machines that target at the process of packing of products, they will execute the identical amount of operations approximately. Wide introduction of microprocessors and mechatronic control system gives an opportunity to create the packing machines-automats of new generation [2]. Creation of such generation of packing machines is based on their hierarchical construction from the functional system of the mechatronics modules. In this case for optimization of packing process it is needed to optimize the structure of machine with taking into account of mechatronics connections. As a rule in the technical systems consider that a synthesis is project procedure. As a result combination of the different modules (elements) comes true in single unit - machine (system) [3].

Materials and methods

In engineering sciences of understanding of synthesis will divide into three components: to the synthesis of construction, synthesis of parameters and synthesis of structure.Procedure of synthesis of structure of machine in the theory of the automated planning is the not very studied process [4].

Methods the adopted by the combinatorics of logistic found most application in the automated planning among plenty of tasks based on a structural synthesis.

Ці способи базуються на загальній теорії комбінаторики.

These methods are based on the general theory of combinatorics [5,6,7].

Id est for this purpose, to do structures, it is necessary to do sorting and search of new combination in the array of analogues and prototypes.

This method will be effective at such accepted suppositions [8]:

- the technical system (packing machine) has the developed structure with large amount of elements and connections;
- a packing machine belongs to the class of objects that have the identical functional setting;
- the great number of analogues and prototypes has considerable power for the effective search of new combinations in such combinatorics space;
- the functional modules of packing machines may have are characterized good ability for by a combinatorics

This method of synthesis can be to such facilities of description of the generalized structures of packing machines: [9,10] tabular, logical and network models of algebra.

Widest application among these models got morphological tables, many-particle columns (N - partial), alternative trees (And are trees, I-АБО-trees) and oriented multigraph.

Method of oriented multigraphs most perspective among of the enumerated methods of description of structure [11].

Results and discussion

The oriented multigraphs are this generalization of the oriented graphs. They appear from the directed multiedges that can have a few entrances and a few exits in a general case.

On a picture the presented process of packeting of products in a consumer container as multigraph.

The technological process of packing consists of such basic and auxiliary operations.

Z_1 – environment; Z_2 – preparation of products; Z_3 – forming of consumer container; Z_4 – dosage of products; Z_5 – preparation of consumer container (pack) is to packing; Z_6 – packing of products; Z_7 – sealing-in of packing; S_1 – properties of products; S_2 – properties of packing material; S_3, S_4 – properties of products and packing material; S_5, S_6 – properties of dose of products and formed packing; S_7 – properties of the packaged products and packing; S_8 – properties of packing unit.

In practice packing processes have a considerable great number of variants of sequence for implementation of technological operations.

In given the applied technological operations are elements that form the combinatorics surplus structure of process.

In accordance with understanding the operations is are multiribs. Their entrances of Si describe the sequence of implementation.

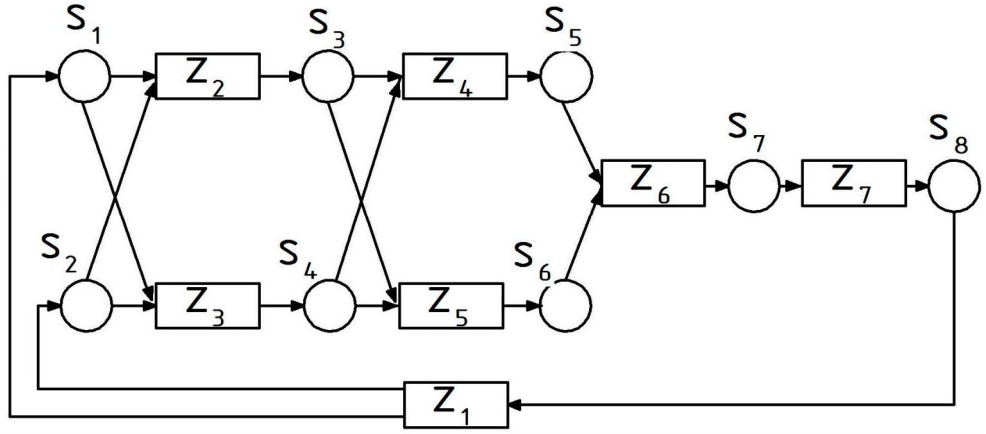

Fig. 1. The oriented multigraph describes about the generalized structure of technical process packing of food products in a consumer container.

During packing of products there are terms of use of operation there are the fixed values: exactness of dosage; impermeable parameters of packing; durability of welding or glue is on sutures; exactness and quality marking, for auxiliary packing facilities and others like that.

Realization of operation allows to change these descriptions, that gives an opportunity to apply other operations.

An operation of packeting will be complete on condition of receipt of new numeral parameters.

A combinatorics logical model gives new decisions at the reasonable association of elements. combinatorics of association gets the great number of variants that give an opportunity to decide the task of optimization for multigraphs on condition of large number of connections elements.

The compact and well-organized structure of technological process (Fig.1) will ground to count her decision as some the multiways for conducts from the great number of tops (S1, S2) to the great number of S8.

On a picture the present structure as a general and simple, but in the real terms the process of packeting consists of great number of the stages (elements) and they can be realized by different structural working organs.

In such case it is needed to have methodology.

If through in (Z) to designate the entrances of arc of Z, and through out (Z) are exits of Z and great numbers of multiarcs - C, then in (C) will enter structures of C, and out (C) her exits.

A structure is named a multicycle, if for it correlation of in (C) = D is executed, id est it has an empty set of entrances.

The decision of task of structural synthesis consists in any not surplus multicycle that contains the element of Z1, id est environment.

Taking into account of element of Z1 guarantees globalness of multicycle. It means that it, in accordance with a requirement specification on planning of packing machine, connects entrances and exits of environment and does not close on some local elements that is located into multigraphs.

Not surplus means that a multicycle does not contain superfluous elements, what unnecessary for the decision of the put task.

The thus oriented multigraphs is flexible, more expressive next to other methods of presentation of structure.

Be what generalized structure can be described by the language of multigraphs without the losses of information. The oriented multigraphs give an opportunity to synthesize valuable structures in that there are copulas between elements. It is important properties of multigraphs, because morphological matrices, alternative trees generate the most primary type of structure.

Connectedness, combinatorics power, ability to describe multifunction elements - all these properties of oriented multigraphs give an opportunity to decide the tasks of structural optimization [8].

For the decision of these lacks of task of structural synthesis decide in discrete programming mathematical form.

During of this method one class of packing machines is for as oriented multigraphs. In such multigraphs by the great number of multiarcs is $Z=\{Z_i\}$, $i=\overline{1,n}$ and great number of top – $S=\{S_i\}$.

Formalization of task is taken to the following:

1. Z_i, $i=\overline{1,n}$

for $Zi=\begin{cases}1, \text{if an arc is included in a decision;}\\ 0, \text{if an arc is not included in a decision.}\end{cases}$

2. $y_{i,j}$, $i=\overline{1,n}$, $j=\overline{1,r_j}$ де $y_{i,j}$ – exit of element Z_i under a number j, a r_i – common amount of exits of element Z_i.

It is possible to consider that:

$$y_{i,j}=\begin{cases}1, \text{if j initial connection of element of } Z_i \text{ is activated;}\\ 0, \text{if in initial connection of element of } Z_i \text{ not activated.}\end{cases}$$

3. x_{ik}, $i=\overline{1,n}$, $k=\overline{1,m_i}$, де x_{ik} – k- entrance of element Z_i, a m_i – incurrence of entrances of this element.

Will consider that:

$$x_{ik}=\begin{cases}1, \text{ if } k \text{ - entrance connection of element of } Z_i \text{ is activated;}\\ 0, \text{ if } k \text{ - entrance connection of element of } Z_i \text{ is not activated.}\end{cases}$$

Z_i, $y_{i,j}$, x_{ik} – the variables for a record systems of limitations and objective function in the task of structural synthesis on elements with restrictive combination.

If it is needed to take into account physical terms then enter auxiliary arguments.

The decision of task of structural synthesis consists of the oriented arcs of multigraphs. An arc will be activated then when all her exits are activated. This condition will write down as such system of equalizations :

$$r_i \times Z_i = \sum_{j=1}^{r_i} y_{ij}; \quad i=\overline{1,n} \tag{1}$$

This system of equalizations is compatible then, when $Z_i=0$ but all variables $y_{i,j}=0$, або $Z_i=1$, всі $y_{i,j}=1$.

For labilizing of element of structure it is needed to revolt all it entrance copulas. It means that $Z_i=1$ then and only after, when $x_{ik}=1$, $k=\overline{1,m_i}$.

If $x_{ik}=0$, then $Z_i=0$. For the record of this condition in the type of algebra will enter n of auxiliary variables $u_i \in \{0,1\}$, $i=\overline{1,n}$. In such case will consider the set of inequalities :

$$\sum_{k=1}^{m_i} x_{ik} - m_i \geq -m_i u_i; \tag{2}$$

$$Z_i - 1 \geq -u_i; \tag{3}$$

$$\sum_{k=1}^{m_i} x_{ik} \geq m_i Z_i; \tag{4}$$

$$\sum_{k=1}^{m_i} x_{ik} - m_i < 1 - u_i; \quad for \quad i=\overline{1,n} \tag{5}$$

Possibly $Z_i=1$. At this condition subsystem (3) executed at be what values u_i. From (4) it goes out that $x_{ik}=1$, $k=\overline{1,m_i}$. Subsystem (5) assumes an air $0<1-u_i$ from $u_i=0$, $i=\overline{1,n}$ and subsystem (2) executed automatically.

If $Z_i=0$, then system (4) executed automatically for be what values of arguments in left her part. Subsystem (3) taken to the kind $u_i \geq 1$ what has an only decision, $u_i=\overline{1,n}$, $i=\overline{1,n}$, Putting these values in expressions (2) and (5) obsessed:

$$\sum_{k=1}^{m_i} x_{ik} \geq 0; \qquad \sum_{k=1}^{m_i} x_{ik} < m_i.$$

For formalization of condition of indignation of entrances of elements of the generalized structure of packing process all variables of kind x_{ik} та y_{ik} it is needed to put in order graphic methods on the values of their indexes. After this operation every variable $x_{ik}(y_{ik})$ will get a new single index $\alpha(i,k)$, $\beta(i,j)$, what shows the number of variable in the graphic order.

Will designate through $M = \sum_{i=1}^{n} r_i$; *and* $K = \sum_{i=1}^{n} m_i$;

A rectangular matrix is possibly set (0,1) $P = \left\| p_{ij} \right\|$ to the size K x M, in that:

$$p_{ij} = \begin{cases} 1, \text{if entrance } x_i \text{ provided with exits } y_i; \\ 0, \text{if entrance } x_i \text{ not provided with exits } y_i; \end{cases}$$

Then set of inequalities that formalize the condition of providing of indignation of entrances it is possible to write down in such kind:

$$\sum_{j=1}^{M_i} p_{ij} \geq x_i; \quad i = \overline{1,k} \tag{6}$$

In this expression of i and j - number of variables of x_i, y_j in the new graphic order.

If x_i, then there will be even one constituent of kind in a that sum 1×1. It means that the activated exit that will provide an entrance is x_i. If x_i=0, then inequality is executed automatically.

Be what faithful decision of task of structural synthesis must execute the put requirement specification and answer the functional setting. For this purpose it is needed and enough to plug in development an element that characterizes an environment. This condition can be written down as expression:

$$Z_1 = 1. \tag{7}$$

System equalizations of inequalities (1) – (7) represents basic physical sense of task of structural synthesis on the generalized structure of packing machine, that over is brought as the oriented enormous count.

Be what decision of this system presents by a possible variant of structure of packing machine. The system is open because assumes including of additional limitations that take into account the features of making decision in a certain situation. By means of the entered variables it is possible to set forth different terms that limit combination of structural elements generally speaking to access. Next to it systems of equalizations (1) – (7) it is invariant, and also it can be used in combination with different objective functions.

Objective functions, for the decision of far of project situations, it can write down in a kind:

$$\sum_{i=1}^{n} Z_i \rightarrow \min \tag{8}$$

$$\sum_{i=1}^{n} C_i Z_i \rightarrow \min \tag{9}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{r_i} y_{ij} \rightarrow \min \tag{10}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m_i} x_{ij} \rightarrow \min \tag{11}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{r_i} y_{ij} + \sum_{i=1}^{n} \sum_{j=1}^{m_i} x_{ij} \rightarrow \min \tag{12}$$

Will analyse the brought having a special purpose units over.

Function (8) minimizes the amount of elements of structure. At all equal terms such decision gives an opportunity to get a packing machine with higher operating properties and more simple in making.

Function (9) minimizes the self-weighted sum of structural elements. Weigher coefficients can be different after physical semantic numerical descriptions and indexes. For example, it can be cost, mass, sizes and others like that, id est those that compare to the parameters of the generalized structure. Objective functions (10) – (12) minimize the incurrence of entrances, exits, and also incurrence of all connections between the chosen elements. At implementation of these terms packing machines will have higher reliability indexes and less charges on service.

Thus all dependences that characterize the generalized structure are linear, and the range of definition of variables is a great number {0,1}. The put task to the search of optimal structure of packing machines behaves to the tasks of the linear boole programming. The methods of decision of models of this type are deeply enough represented in the results of researches [12,13]. Common amount of variables in such models is determined the from expression 3n+K+M, and an amount of equalizations and inequalities is in the system of limitations -7n+K+L+1, so n – common amount of elements of the generalized structure of packing machine K – amount of initial connections; L – amount of the forbidden combinations.

Conclusion

1. Among the numerous methods of structural synthesis that has wide searchabilities there in space of analogues and prototypes.is oriented multigraphs.
2. This method of decision of task gives an opportunity to get the structures of packing machines that are basis for realization of tasks of optimization of structure.
3. For the correction of basic defect of multigraphs are largenesses and impossibility to describe the additionals what for fixed at choice elements, it is suggested to erect the problem of structural synthesis to the tasks of the discrete linear programming. The systems of limitations, that determines the terms of choice of elements of мультіграфовій model, and objective functions that give an opportunity to optimize different structural descriptions of decisions, selected this purpose.

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