

Multicriteria Evolutionary Structural Parametric Synthesis of Technological Process on the Basis of Simulation

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Abstract

This article discusses an urgent issue of structural parametric synthesis of technological processes assuming conversion of preset input signal into the required reference signal via intermediate system states. Such methods are widely applied upon development of intelligent advising systems. In order to solve labor intensive synthesis problem of such systems, it is assumed to apply combined approach based on evolutionary methods, Petri nets and simulation. This article describes adaptation of genetic algorithm which permits both structural and parametric synthesis of technological processes. This is exemplified by a technological process of plant cultivation.

Key words: system analysis, structural parametric synthesis of technological processes, evolutionary algorithms, genetic algorithm, Petri nets, simulation, intelligent systems.

1 Introduction

Structural parametric synthesis of technological processes is a variant of more general scientific and practical problem: synthesis of systems with preset behavior capable to convert a preset input vector (data, substance, energy, etc.) into a required output vector [1-3], herewith, situations are possible when the system should pass through preset states, such states can be considered as various stages of technological process.

In order to develop mathematical apparatus of structural parametric synthesis of technological process it is required: to describe technological process using IDEF3 method of presentation of elements and their interaction; to develop models and methods of structural synthesis of technological process; to define

functioning parameters of elements of technological process; to develop models and methods which permit to form structure of technological process; to adopt structural synthesis model to solution of structural parametric synthesis problem. This work presents models and methods which permit to solve the problem of structural parametric synthesis of technological processes. Most problems in this area can be referred to multicriterial and multiextremal class, that is, in addition to numerous factors effecting both the solution itself and its progress, several solutions are possible meeting the synthesis criteria.

One of the well behaved methods for solution of synthesis problems, optimization and simulation by random selection, combination and variation of the required structures and parameters is genetic algorithm. Its application will make it possible to decrease synthesis time of configuration of technological processes in various areas not only with modification of system elements but also with modification of settings of elements included in the system models.

2 Methods

Genetic algorithms

The genetic algorithm, selected as a tool of structural parametric synthesis, reproduces principles of natural selection, that is, survival of the most promising specimens, inheritance and mutations [2, 3].

Functioning of genetic algorithm in the considered subject area of parametric synthesis of technological processes in agriculture can be presented as follows.

At first it is required to make inquiries of experts, to determine model of technological process: elements, links, functioning parameters. In order to determine the process structure, it would be reasonable to apply the IDEF3 method which considers for logical

elements as crossings. On the basis of expert opinion, a library of element models is developed using mathematical apparatus of Petri nets. Such approach would permit to structure population chromosomes of genetic algorithm. Since the genetic algorithm operates with binary string, then it is required to present element models in the form of binary code string, this can be implemented by application of binary trees of equal length.

Adaptation of genetic algorithms in various areas

While adopting genetic algorithm to the problem of structural parametric synthesis of technological process in the area of plant cultivation, let us develop the model for cultivation of winter wheat using modern No-Till technology (Fig. 1).

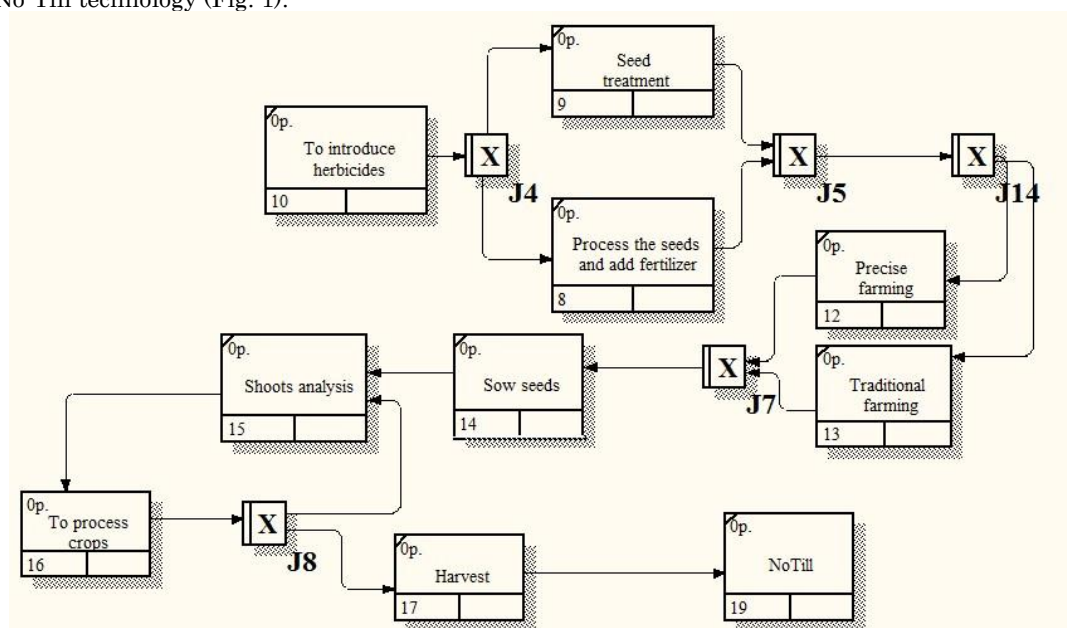


Fig. 1. Cultivation of winter wheat using No-Till procedure

Application of Petri nets for description of genetic algorithms

The developed models of technological process can be presented in the form of Petri nets. While implementing the genetic algorithm by Petri nets, it should be taken into account that not a single net level would be required. The upper level should describe operation of genetic algorithm itself and the lower level should contain models of synthesized technological processes. Therefore, of all variety of

Simulation of components and their interrelation in

the proposed model of intelligent structural synthesis is based on the theory of Petri nets. Each process can be performed by various machines, equipment and various agricultural reagents. Hence, for each process it would be reasonable to develop models of each procedure with accounting for appropriate specificity which would participate in structural parametric synthesis of technological process. Crossing triggering is simulated by transitions of Petri nets. Function can be performed on these transitions. One of the variants is application of production rules from knowledge base as a rule of label transition.

Petri net extensions such one should be selected which would support independence of subject area, probability and determinacy, structural and multilevel properties. Such extension is nested Petri nets. In this extension labels of each level can be presented by Petri net [1], which permits to describe technological process by models of various nesting types. Figure 2 illustrates No-Till model of soil cultivation on the basis of Petri nets.

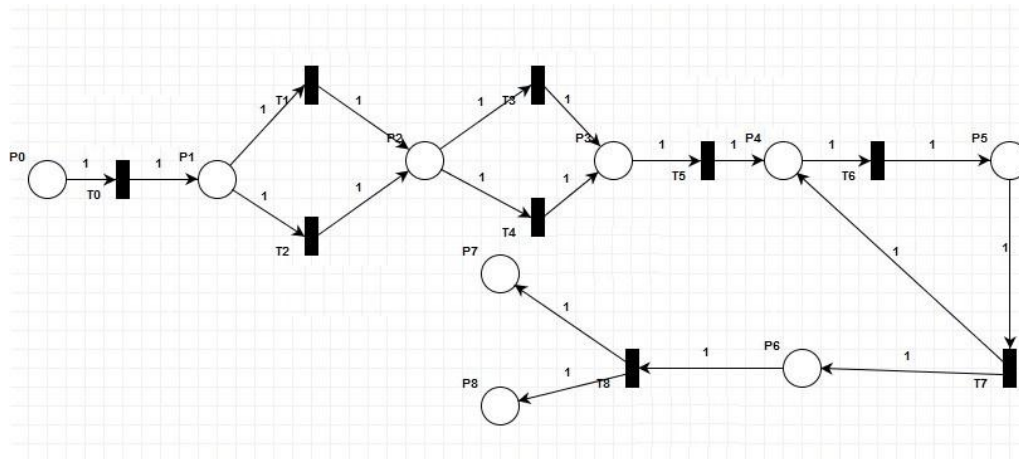


Fig. 2. No-Till model on the basis of Petri nets

3 Results

Formulation of the problem

Let us consider the following class of structural parametric synthesis of technological processes.

It is given: $S = \langle \text{Input}, C, O_f, MK, T_f, M, \text{Output} \rangle$,

where S is the technological process, the structural parametric synthesis of which should be performed; Input are the process inputs; Output are the process outputs; C are the elements of the process; O_f are the links of element C_i , the functions of which effect the functioning parameter; MK is the element of intercomponent process bus S ; T_f are the functional components of element C_i and MK_i , their values effect the parameter of its functioning; M is the initial state of elements C_i of process S . Let us write down the elements of technological process: $C = (C_1, \dots, C_R)$, where C_i is the i -th component of technological process, R is the number of components. $C_i = \{C_{ij}\}_{j=1}^{M_i}$, where C_{ij} is the j -th copy of the i -th component, M_i is the number of copies of the i -th component. $P = \{P_k\}_{k=1}^L$, where P is the set of properties which can be attributed to the synthesized technological process with preset behavior, P_k is the k -th property of the set P , L is the number of properties of the set P .

$$O = (O_1, \dots, O_R)$$

$$O_i = \{O_{ij}\}_{j=1}^{M_i}$$

$$O_{ij} = \langle \text{Type}O_{\text{start}}, NE_{\text{start}}, N_{\text{outstart}}, \text{Type}O, NE_{\text{end}}, N_{\text{inend}} \rangle,$$

where $\text{Type}O_{\text{start}}$ is the link type; NE_{start} is the number of element from which the link originates (should be determined by the number of element C_i or the number of element of intercomponent bus MK_i); N_{outstart} is the output number of element from which the links originates; $\text{Type}O$ is the link type; NE_{end} is the number of end element for link determined by the number of element C_i or the number of element of intercomponent bus MK_i ; N_{inend} – is the input number of element C_i or input number of element of intercomponent bus MK_i .

Let us write down the elements of intercomponent bus:

$$MK = \langle \text{Type}MK, \langle \text{Type}MK_f \rangle \rangle,$$

where $\text{Type}MK$ is the type of intercomponent element; $\text{Type}MK_f$ is the element component of

intercomponent bus, the value of which effects its functioning (not accounted in coding).

Let us write down functional components of elements C_i and MK_i , the values of which effect the parameter of its functioning:

$$T_f = \langle \text{Type}E, \langle T_{E_f} \rangle \rangle,$$

where $\text{Type}E$ is the element type; T_{E_f} is the element component, the value of which effects its functioning (not accounted in coding)..

$$M = \langle \text{Type}E, \langle M_0 \rangle \rangle,$$

where $\text{Type}E$ is the element type; M_0 is the initial state of element.

It is required: for preset behavior peculiar for technological process S to select by one copy of each component C_i and parameter of its functioning so that the process would possess preset behavior, that is, would be able to convert a preset input vector into the required output one.

Solution of the problem

In order to solve the problem of structural parametric synthesis, it is required to prepare element base of component models based on Petri nets. In these models it is necessary to determine functional links and transitions effecting the operation of element model; to determine possible initial labels for elements, which will reflect the initial state of element of the synthesized technological process. Then, chromosomes of initial population should be formed in the form of binary code string; in its turn, it can be expanded in Petri net by means of matrices P/T , T/P and M_0 [4, 5]. The target function can be calculated by the degree of provision of the required response of technological process; by the degree of provision of preset behavior. This is aided by preset series of input vectors and series of output vectors, as well as by intermediate states of the synthesized technological process. The degree of approximation to the required solution can be estimated by Hamming distance and tree of graph of realizable labels. In addition, penalty function can be used.

4 Discussion

This work describes adaptation of genetic algorithm to subject area of structural parametric synthesis, as well as simulation using the theory of Petri nets.

Various parameters of the proposed procedure can provide various solutions of the synthesis problem which can be combined in selection set, then final decision is selected by a decision maker on the basis of personal (sometimes not formalized) preferences. Therefore, it would be reasonable to apply this approach upon development of intelligent systems supporting decision making.

5 Conclusion

The main result of this work is formalization and algorithmization of structural parametric synthesis of technological processes based on preset behavior using solution on the basis of preset components and parameters of their operation.

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