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THE EXPERT SYSTEM FOR COMPUTER-AIDED INVESTIGATION OF PRINCIPAL PNEUMATIC DIAGRAMS OF COMBINATORY AUTOMATES

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Abstract. *In order to examine the realization of the principal pneumatic diagrams of a combinatory automate, direct connection and control by the combinatory diagram are most frequently applied. This manner of examination is rather slow, and if any errors occur re-connecting is required.*
The automated investigation of the principal pneumatic diagram of a combinatory automate, with the aid of personal computer and by using Clips is presented in the paper. This enables to eliminate possible errors before the realization itself takes place.

Key words: *Combinatory automate, Clips, pneumatics, pneumatic diagram, computer.*

1. INTRODUCTION

Combinatory automates fall into the category of finite automates with a fixed number of input and output channels. By using binary signals a program of the technological process is given at the input, and at the output actuators are activated i.e. the appropriate technological operations are performed.

With this type of automate the state of the output is determined only by combining the values of input signals, present in the observed moment, regardless of the preceding input combinations. It is as well determined by the logic of the automate. It is, therefore, said that these automates have no memory. The input variables (independent variables – x_i, i=1,2,...n) and the output variables (dependent variables – y_j, j= 1,2,...m) have a binary value (0,1).

The given functional dependence of combinatory automates can be expressed by using logical functions so that the procedure of their synthesis is based on using the familiar minimization methods in order to obtain the most favourable solution for technological realization.

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2. PROGRAM TOOL-CLIPS

CLIPS (***C*** *Language* ***I****ntegrated* ***P****roduction* ***S****ystem*) is a tool for developing expert systems which consists of the following elements:

1. list of facts,
2. base of knowledge, and
3. deduction machine.

The program written in CLIPS is composed of rules, facts and objects. Deduction machine decides which rule and when will be applied. The expert system based on the rules and written in CLIPS is a data-controlled program in which the facts and objects are the data which stimulate the performance via deduction machine.

The list of facts of the program for automated investigation of pneumatic diagrams consists of:

- Base of elements (BAZA.TXT) containing data about the manner of slide valve gear operation, AND and OR valves.
- Diagram (SEMA.TXT) containing data about the manner of connecting the elements of the pneumatic diagram.
- Input (ULAZ.TXT) containing the input combinations of the combinatory automate.

After entering these data files the program checks the principal pneumatic diagram on the basis of the list of rules. If the diagram is correct at the input we obtain the value of output for a certain combination at the input. If the diagram is incorrect the program indicates the connection error.

3. MANNER OF PROGRAM OPERATION

The programs written in Clips consist of a sequence of rules; in order to execute these, the left-hand side of the rule should be fulfilled. Namely, it is necessary for the facts which make up the left-hand side of the rule to exist; thus, the rule can be executed and if the program has been started, the rule itself will be executed, whereby a change in the fact list occurs in the form of reading-in of new facts or deleting the old ones.

The program described in this paper consists of several rules as well, to be more precise, of twelve rules, which are executed in the aforementioned manner.

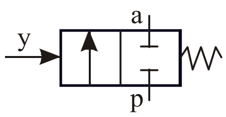
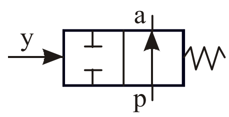
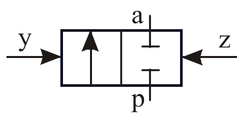
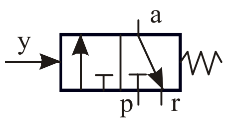
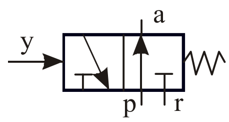
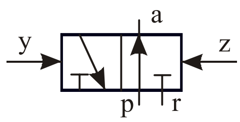
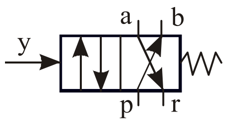
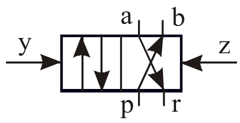
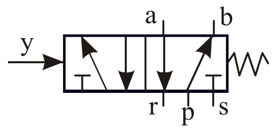
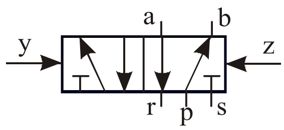
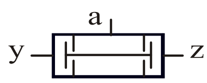
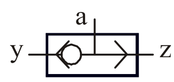
In order to enable the execution of the program, after it has been opened, the fact (initial-fact) should be read in by using the directive (reset), and started by directive (run). The rule pocetak (start) can now be executed since on its left-hand side there is only a fact (initial-fact). The execution of this rule results in reading-in of the base of elements (BAZA-ELEMENATA), fact list referring to the diagram itself (SEMA) and list of input facts (ULAZ). The content of the base of elements and fact list can be altered (edited) by a simple text editor.

It is now possible to execute all the other rules.

The rules that contain the "veza-element" in their name are the rules which, on the basis of data about the element to which they are linked, data about the element being linked, data of the connection itself and rule of manner of operation of the element being linked, enable that the element being linked changes its state and the executed connection transforms in a used connection. There are seven rules in this group differing in whether the input elements (elements to which others are linked) have two, three, four or five inputs and whether their *a* or *b* input is connected to the element being linked.

Under the term "element" we mean the pneumatic valves with the corresponding inputs and outputs, as shown in Table 1.

Table 1

 Valve 2/2 normally closed (r2/2-z)	 Valve 2/2 normally opened (r2/2-o)	 Valve 2/2 bistable (r2/2)
 Valve 3/2 normally closed (r3/2-z)	 Valve 3/2 normally opened (r3/2-o)	 Valve 3/2 bistable (r3/2)
 Valve 4/2 monostable (r4/2)	 Valve 4/2 bistable (r4/2)	 Valve 5/2 monostable (r5/2)
 Valve 5/2 bistable (r5/2)	 AND valve	 OR valve
The inputs into elements are marked with: p, r, s, y, and z. The outputs out of elements are with: a and b.		

For the purpose of a simpler explanation we will present the rule veza-elementa-sa tri-ulaza-i-a:

Field marks:

?bn-Number of levels;
?r1, ?r2- element mark (r2/2, r3/2-z, r3/2-o, r4/2, r5/2, I and ILI);
?n1- the first digit in marking the element to which others are linked;
?a- the second digit in marking the element to which others are linked;
?a1-mark of the first input of the element to which others are linked;
?a2- value of the first input of the element to which others are linked;
?a3-mark of the second input of the element to which others are linked;

?a4-value of the second input of the element to which others are linked;
?a5-mark of the third input of the element to which others are linked;
?a6-value of the third input of the element to which others are linked;
?n2- the first digit in marking the element being linked;
?b- the second digit in marking the element to which others are linked;
$?napred- fields in front of mark of the input being linked;
?u- mark of the input of the element being linked;
?u+1-value of the input of the element being linked;
$?iza-fields behind the value of output a of the element to which it is linked.

Let us cite as an example the elements 6.1 and 5.1 from Figure 2. and their connection and rule of operation of elements 6.1:

(nivo 6)

(gotov veza 6 1 a 5 1 y).

Once there are no more connections in the corresponding level, the rule prelaz-1 is executed and the lower level asserted; therefore, the program can proceed operating. In the previous example it is (nivo 5).

Should, during the execution of the program, a FORBIDDEN-STATE occur on any element, the rule zabranjeno-stanje-1 sends a message about the presence of such a state and the manner of testing.

The program is executed up to the level 0 (nivo 0). Then, if everything is in order, the rule izlaz-1 or izlaz-2 sends a message about the value of the output.

4. EXAMPLE OF THE APPLICATION OF PROGRAM

The pneumatic press in Figure 1 is supplied with four pneumatic sensors (1, 2, 3, 4), which should start the press:

(1) - for control of the basic position;
(2) - for start of the operation cycle;
(3) - for registering the work piece in the tool and
(4) - for adjustments.

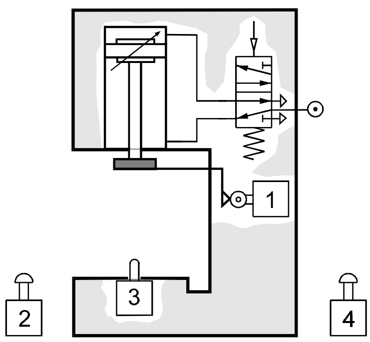


Fig. 1. The press operation conditions are given in the form of a combinatory chart: table 2.

Table 2.

i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
x_1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	2^3
x_2	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	2^2
x_3	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	2^1
x_4	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	2^0
y	0	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	

If we proceed, we obtain the minimal disjunctive normal form –MDNF with the smallest number of elements: formula

$$y_{min}=\bar{x}_1\bar{x}_2x_4+\bar{x}_2x_3x_4+x_1x_2x_3\bar{x}_4=\bar{x}_2x_4(\bar{x}_1+x_3)+x_1x_2x_3\bar{x}_4$$

On the basis of MDNF a principal pneumatic diagram, presented in Fig. 2, can be drawn.

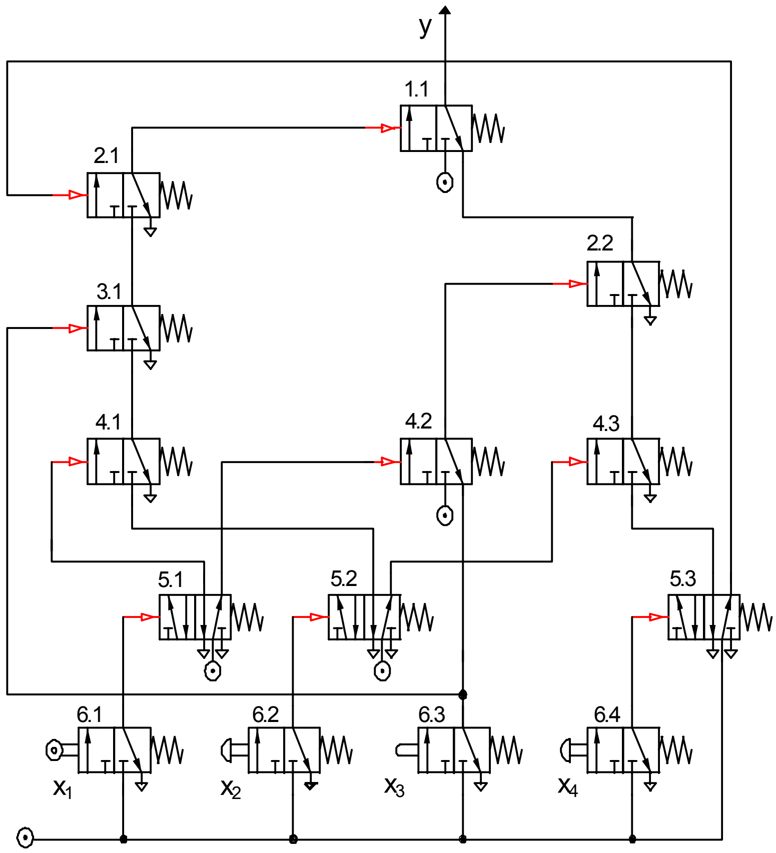


Fig. 2.

Based on the principal pneumatic diagram, data are entered into data file SEMA.TXT:

(initial-fact)
(nivo 6)
(element r3/2-z 1 1 y 0 p 1 r 0)
(element r3/2-z 2 1 y 0 p 0 r 0)
(element r3/2-z 2 2 y 0 p 0 r 0)
(element r3/2-z 3 1 y 0 p 0 r 0)
(element r3/2-z 4 1 y 0 p 0 r 0)
(element r3/2-z 4 2 y 0 p 1 r 0)
(element r3/2-z 4 3 y 0 p 0 r 0)
(element r5/2 5 1 y 0 s 0 p 1 r 0)
(element r5/2 5 2 y 0 s 0 p 1 r 0)
(element r5/2 5 3 y 0 s 0 p 1 r 0)
(veza 6 1 a 5 1 y)
(veza 6 2 a 5 2 y)
(veza 6 3 a 3 1 y)
(veza 6 3 a 4 2 r)
(veza 6 4 a 5 3 y)
(veza 5 1 a 4 1 y)
(veza 5 1 b 4 2 y)
(veza 5 2 a 4 1 p)
(veza 5 2 b 4 3 y)
(veza 5 3 a 4 3 p)
(veza 5 3 b 2 1 y)
(veza 4 1 a 3 1 p)
(veza 4 2 a 2 2 y)
(veza 4 3 a 2 2 p)
(veza 3 1 a 2 1 p)
(veza 2 1 a 1 1 y)
(veza 2 2 a 1 1 r)

When the SEMA.TXT data file has been formed, we proceed to enter data into ULAZ.TXT data file.

−By entering the input values from the combinatory chart for decimal equivalent 10:

(element r3/2-z 6 1 y 1 p 1 r 0)
(element r3/2-z 6 2 y 0 p 1 r 0)
(element r3/2-z 6 3 y 1 p 1 r 0)
(element r3/2-z 6 4 y 0 p 1 r 0)
we obtain the output, y:

Element 1.1
Output y: 0

−By entering the input values from the combinatory chart for decimal equivalent 11:

(element r3/2-z 6 1 y 1 p 1 r 0)
(element r3/2-z 6 2 y 0 p 1 r 0)
(element r3/2-z 6 3 y 1 p 1 r 0)
(element r3/2-z 6 4 y 1 p 1 r 0)
we obtain the output, y:

Element 1.1
Output y: 1

In this manner it is possible to check the principal pneumatic diagram for the appropriate automate for each of the input combinations from the combinatory chart.

5. Example of determination of error in realization of pneumatic diagram

For the pneumatic diagram presented in Figure 3, we need to examine whether the realization of the diagram has been adequately performed.

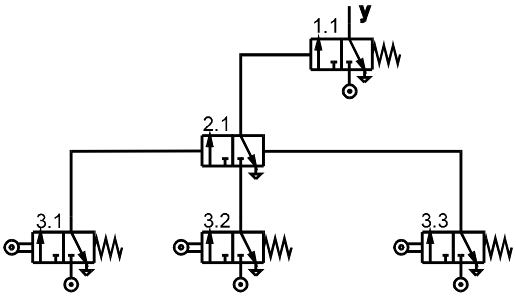


Fig. 3.

Data referring to the principal diagram itself.

(initial-fact)
(element r3/2-z 1 1 y 0 p 1 r 0)
(element r3/2 2 1 y 0 p 0 r 0 z 0)
(veza 2 1 a 1 1 y)
(veza 3 1 a 2 1 y)
(veza 3 2 a 2 1 p)
(veza 3 3 a 2 1 z)
(nivo 3)

When sensor 3.1 is 1, sensors 3.2 1 and 3.3 0 have the values:

(element r3/2-z 3 1 y 1 p 1 r 0)
(element r3/2-z 3 2 y 1 p 1 r 0)
(element r3/2-z 3 3 y 0 p 1 r 0)

The output, y is:

Element 1.1
Output is: 1

When sensor 3.1 is 1, sensors 3.2 0 and 3.3 1 have the following values:

(element r3/2-z 3 1 y 1 p 1 r 0)
(element r3/2-z 3 2 y 0 p 1 r 0)
(element r3/2-z 3 3 y 1 p 1 r 0)

The output we obtain is the following message:

Forbidden state-Check the input signals for y and z channels of element 2.1

At this level of the expert system the computer only detects the forbidden states if they exist. At the following, more advanced level the computer can solve the existing mistakes; however, it is not included in this paper.

6. Conclusion

The paper presents the utilization of only some of the possibilities of CLIPS tool for development of expert systems; nonetheless, it enables a prompt investigation of the pneumatic realization diagrams of a combinatory automate. The program itself offers a solid basis for its further advancement for sequential automates as well.

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EKSPERTNI SISTEM ZA PROVERU PRINCIPIJELNIH PNEUMATSKIH ŠEMA KOMBINACIONIH AUTOMATA POMOĆU RAČUNARA

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Dosadašnja provera ispravnosti principijelnih pneumatskih šema kombinacionog automata vršila se neposrednim povezivanjem, pri šemu je taj proces bio spor i ukoliko bi se otkrila neka greška bilo je potrebno vršiti naknadno prevezivanje.

U ovom radu prikazan je automatizovan način provere principijelnih pneumatskih šema pomoću računara koristeći CLIPS ekspertnu ljusku.

Ovim načinom provere omogućuje se otkrivanje i otklanjanje grešaka i pre samog povezivanja.