DYNAMIC SYSTEM

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SUMMARY

The paper deals with a quite new conception of logic control. The conception model of the program CA (Control Automaton) will be set up on CA with a failure input, whereas a feedback CA can do without a failure input. CA is a static system, i.e. it is a minimal one, with respect to the number of states

Keywords: *state, dynamic logical system, system of automatic logic control.*

1. INTRODUCTION

The paper freely follows up with [1, 17], and shows, without superfluous formalism, that it is of necessity to fundamentally revise the current conception of automatic logic control.

Further on, it will be necessary to examine the content (meaning) of the following concepts: state, causality, dynamic logical system (*DLS*), and system of automatic logic control (SALC).

2. STATE, CAUSALITY, DYNAMIC LOGICAL SYSTEM

A dynamic logical system in [2 -7] is defined as an ordered quartet at least

$$A = \langle X, S, \delta, s_{\mathrm{I}} \rangle \tag{1}$$

(a finite initial semiautomaton) where X, S are input and state alphabets, respectively, and δ is a transition relation, spec. function

$$\delta : S \times X \times S : \langle s, x, s' \rangle , \tag{2}$$

spec.

$$\delta : S \times X \to S : \langle s, x \rangle \mapsto s' . \tag{3}$$

In particular, let us emphasize that the notation of the follower state s' with respect to the initial state is inaccurate as it is the case of prediction s', namely a possible, spec. a certain one, which cannot be found in the system, because it is located in the inner or in then help output memory of the subject which identifies the given system. Let anticipation belong to metaphysics.

A transition relation, spec. function δ defines, together with the initial state s_{I} the state s of the system in a recurrent way

- the initial state s_{I} is the state
- if s is a state, then also $proj_3(s, x, s')$, spec. $s' = \delta(s, x)$ are states
- other states do not exist.

To define the state *DLS* as its entire input history [5] ξ, or ζ ($\xi \neq \zeta$) is not acceptable, but $\delta(\xi, x) = \xi x = \delta(\zeta, x) = \zeta x$; is feasible. Neither Nerode's definition of a state as a class of the finite decomposition of the entire input history [3, 10] can hold out since it assumes the existence of a class $\{e\}$ with an empty word e as the representative of it. A metaphysical acceptance of e by the automaton is considered here as reality.

Let the transition relation, spec. function be generalized assuming that an acceptable input word is applied at the system input $x_{\mathrm{i}1} x_{\mathrm{i}2} \ldots x_{\mathrm{if}}$:

$$\delta(s_{\mathrm{I}}, x_{\mathrm{i}1}\, x_{\mathrm{i}2} \ldots x_{\mathrm{if}}, s_{\mathrm{f}}) = \\ = \delta(s_{\mathrm{I}}, x_{\mathrm{i}1}\, x_{\mathrm{i}2} \ldots x_{\mathrm{if}-1}, s_{\mathrm{f}-1}) \circ \delta(s_{\mathrm{f}-1}, x_{\mathrm{f}}, s_{\mathrm{f}}), \tag{4}$$

spec.

$$\delta(s_{\mathrm{I}}, x_{\mathrm{i}1}\, x_{\mathrm{i}2} \ldots x_{\mathrm{if}}) = \delta(\delta(s_{\mathrm{I}}, x_{\mathrm{i}1}\, x_{\mathrm{i}2} \ldots x_{\mathrm{i,f}-1}), x_{\mathrm{if}})$$

Where $\circ$ is the composition operator of relations, spec. functions

In considering causality in the nondeterministic *DLS*, let us replace, in a purely metaphysical manner, all possible follower states of an arbitrary given state with only one certain state of follower in all the cases, and let us examine the causality of the nondeterministic *DLS* as a causality of a deterministic "determinized" *DLS*.

The dynamic system is said to be causal (freely cited according to [2, 3]) if for the validity of the following equality

$$proj_3\{\delta(s, x_i, s'_{\mathrm{i}})\} = proj_3\{\delta(s, x_j, s'_{\mathrm{j}})\} \tag{5}$$

spec.

$$\delta(s, x_{\mathrm{i}}) = \delta(s, x_{\mathrm{j}}),$$

the necessary and sufficient condition is $x_i = x_j$ $(i \neq j)$, since for $x_i \neq x_j$ both $\delta(s, x_i) = \delta(s, x_j)$, and $\delta(s, x_i) \neq \delta(s, x_j)$ $\delta(s, x_i) \neq \delta(s, x_j)$ can be applied.

It is usually stated [9, 10] that the sufficient cause; x always induces in *DLS* a possible or certain transition to the follower state, and if the system has been transferred to the follower state, it must have been due to the necessary cause x. Thus the necessary and sufficient cause represents all the causes of transition.

The authors, however, are of the opinion that the definition of the necessary and sufficient cause of state transition is not correct, neither is the term ”sufficient” itself. Indeed, the sufficient cause x always induces the state transition but only if the necessary cause *s*; has been put into effect, the sufficient cause *x* on its own is not supposed to induce the state transition. In addition,. the necessary cause s does induce the transition in the system, whereas the sufficient cause x only initiates, starts the transition (e.g. if a sailing boat is sailing, a wind certainly blows; if a wind blows, it is just sufficient to set up sail, if there is no wind, then the boat cannot sail even though the sails.

Therefore, we will say that a dynamic system is **causal** if for the validity of equality

$$proj_3\{\delta(s_k, x_i, s'_k)\} = proj_3\{\delta(s_l, x_j, s'_l)\} \tag{6}$$

spec.

$$\delta(s_k, x_i) = \delta(s_l, x_j),$$

the necessary cause $s_k = s_l$ and the sufficient cause $s_k = s_l$ (k ≠ l), since for $s_i = s_j$ and $x_i \neq x_j$ or $s_k \neq s_l$ and $x_i = x_j$, or $s_i \neq s_j$ and $x_i \neq x_j$ both $\delta(s_i, x_i) = \delta(s_j, x_j)$ and $s_k = s_l$ $\delta(s_i, x_i) \neq \delta(s_j, x_j)$ can hold.

Consequently, the current conception of dynamic system causality considers the state as a static one and the motion along the state trajectory

$\delta(s_I, x_{i1}\, x_{i2} \ldots x_{if}, s_f)$ spec.
$\delta(s_I, x_{i1}\, x_{i2} \ldots x_{if}) = s_f$, for $x_{i1} = x_{i2} = \ldots = x_{if} = x$
i.e. $\delta(s_I, x^f, s_f)$ spec. $\delta(s_I, x^f) = s_f$

The ”intermediate state” of the transition explains as being unprompted, unrestrained spontaneous [3,6,7,8], even if it were the case of a deterministic system. According to the authors, the state is to be conceived dynamically and the above mentioned state trajectory is the proper motion of the system itself. Nevertheless, according to [11], the effects in nature are derived from inner forces, or according to [12], the attribute dynamic relates to force, as something being based on force, manifesting (inner) force, motion, development; to be kinetic, of force (opposite to static). In addition, let us note that we consider state transitions $\delta(s, x, s')$, spec. $\delta(s, x) = s'$ as instantaneous.

Therefore, if we make the less interesting or unobservable “intermediate state”, in which a real object occurs during the real state transition, identical with the starting state, the action of transition through the state s is conspicuous. If the sensors are sensors of the level, the identification is evident, whereas the pulse sensors as pulse actors will be provided with supporting memories (actorscan also be identified with the follower state s', but only in a formal way, so that it could be possible to construct a transition or Huffman’s table of the automaton).

If we declare that *DLS* is given by its canonic decomposition (Fig..1), where $N = (E, Q, \delta_N)$ is a dynamic substitute of the given dynamic system $A = (X, S, \delta)$ and $I = \langle X \times Q,, E, \lambda \rangle$ is the static system sought for so that in coding k states from A with the states from N - k :

$S \to Q : s \mapsto q$ - it holds [13]

$$k(\delta(s, x)) = k(s') = \delta_N(q_i, \lambda(q_e, x)) = q'_i$$

and $q = q_i = q_e$, then it can be wrongly stated that the “feedback “ state q_e is the necessary cause of the transition from q to q' and from s *to* s', resp. But only the “inner:” state q_i is the necessary cause x whereas the “feedback “state q_e together with x is the sufficient cause x of the transition from q to q' and from s *to* s', resp.

Let us pay attention to identification of the dynamic logical system. In [9] a finite semi-automated model of a box with a square bottom is sought for, the length of its edge being l. It contains three square cubes, the lengths of their edges being $l/2$ (Fig.2.a)), The cubes can be shifted horizontally leftwards (l) or rightwards (r), as well as vertically upwards (u) or downwards (d).

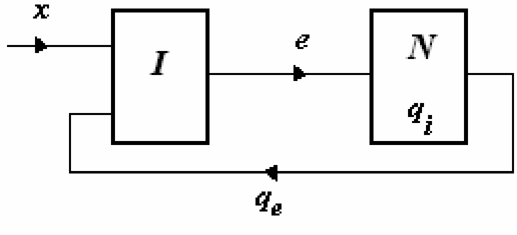

Fig. 1 Canonic decomposition.

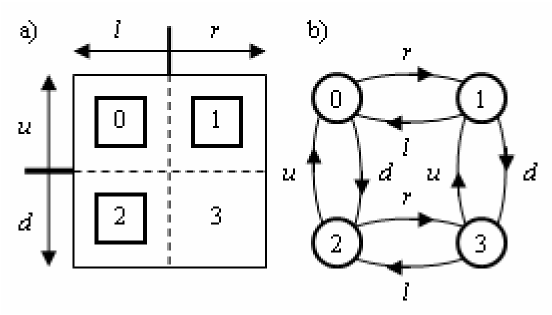

Fig. 2 a) Playing box, b) its transition graph.

The model of the box is said to be an automaton with a transition diagram according to Fig. 2. b). But the subject identifying a play box (Fig. 2.a)) could never be constructed by its automaton model (Fig. 2. b)), unless it identified itself, unaware, with the control automaton (CA) of the box, and unless it ideally simulated the action of the control automaton. In this way, the subject in fact arrived not at the model of the box itself, but at the model of a dynamic system of automatic logical control, consisting of itself and of the play box, which is by no means dynamic. The box is only ***potentially dynamic*** and so its possible action cannot be modeled by a finite automaton.

Technological devices in themselves are not dynamic systems (even if technologists, as a rule, provide their apparatus with *CA*, so that designers of control automation systems are, in fact , "workless", whereas the dynamic systems are represented by structural models *CA*, (circuits) of dynamic systems designed by canonic decomposition, since the only dynamic elementary substitute is classical delay.

3. IS ESSENTIAL AT ALL THE CONTROL OF A DYNAMIC SYSTEM?

Let *SALC* be given according to Fig. 3.a and let $A = \langle X, S, \delta \rangle$ be a *DLS*. The model of the control static (Bellman) system [13] is *CA* $\langle [S], X, \lambda \rangle$ where λ is considered to be the output function $\lambda : [S] \rightarrow X : [s] \rightarrow x$ where $[S] = S/\{e\}$ and $[s] = s/e$.

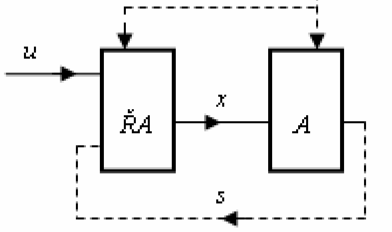

Fig. 3 System of automatic logical control.

Let us assume that, without detriment of generality, state trajectories are given on A :

$$\delta\,(s_{\mathrm{ip}}, x_{\mathrm{i}}^{\mathrm{f}}, s_{\mathrm{if}})\text{, spec. } \delta\,(s_{\mathrm{ip}}, x_{\mathrm{i}}^{\mathrm{f}}) = s_{\mathrm{if}}\ , \tag{7}$$

$$\delta\,(s_{\mathrm{jp}}, x_{\mathrm{j}}^{\mathrm{f}}, s_{\mathrm{jf}})\text{, spec. } \delta\,(s_{\mathrm{jp}}, x_{\mathrm{j}}^{\mathrm{f}}) = s_{\mathrm{jf}}\ , \tag{8}$$

such that $x_{\mathrm{i}} \neq x_{\mathrm{j}}\ (\mathrm{i} \neq \mathrm{j})$, both sides sharing one of the states s . Since A is dynamic, it is sufficient to place an iterated stimulus x_{i} or x_{j} to its input, and if A is in the state s_{ip} or s_{jp} , A moves along the respective state trajectory without *CA* being forced (!) to accept the states of the respective state trajectory. If A arrives at the state s and if the respective *CA,* say x_{i} , which ,ensures the motion of A along the respective state trajectory (i) according to the actual state s of the automaton A , then *CA* will comply with a common requirement to transfer the actual motion of A to the motion of trajectories (j) , i.e. , it will issue according to the state s also x_{i} , only if it is nondeterministic with the output relation $\lambda : S \times X : s \rightarrow x$ so that $\lambda(s, x_{\mathrm{i}})$ and $\lambda(s, x_{\mathrm{j}})$

Solution of the above mentioned trouble lies ready to hand: it is sufficient to control *DLS* directively in the feedforward manner and the control of $u_{\mathrm{i}} = x_{\mathrm{i}}$, $u_{\mathrm{j}} = x_{\mathrm{j}}$ is set by an operator selecting, in this way, the motion of *DLS* along the respective state trajectory (i) or (j) .

Why has the quite evident nondeterminism of *CA* of the nondeterministic *DLS* escaped attention so far? As a model of *CA,* be it a nondeterministic A or a deterministic A with the so called failure input CA, so
$CA = \langle S \times Z,\ X\ ,\ \lambda_Z \rangle$ [14, 15] with the failure input is considered**.** Z is the failure alphabet whose output function is
λ_Z : $\lambda_Z : S \times 2^Z \rightarrow x : \langle s, z \rangle \rightarrow x$, where z is the class of absolute decomposition of Z to Z ($z \in Z$, $Z \subseteq 2^Z$) – see Chap.4.
That would be no problem so far as the effect of failures with *DLS* was recorded by controlling the decision vertices of the flow chart, but it can lead to errors, if for the "beginning (divergence) of sequence selection" [17] a function chart is used.

Example 1.: Let us have $z_1^{\sigma 1}$ - a truck arrives (does not arrive) at the given place (destination), $z_2^{\sigma 2}$ - the given temperature was(was not) reached, $z_3^{\sigma 3}$ - the liquid level $z_3^{\sigma 3}$ - was/was not of the given height ($z^{\sigma} = z\sigma \vee \overline{z\sigma}$ for $\sigma \in \{0,1\}$). Then the failure alphabet will be

$$Z = \mathop{\times}_{i=1}^{3} Z_i = \bigcup_{\langle\sigma_1,\sigma_2,\sigma_3\rangle} \left\{ \bigwedge_{i=1}^{3} z_i^{\sigma_i} \right\}, \qquad (9)$$

where $Z_i = \left\{ z_i^{\sigma_i} \right\}_{\sigma_i \in \{0,1\}}$ and the partition $\mathcal{Z} = \{\mathfrak{z}_i\}_{i=1}^{3}$ to Z let be such that
where $\mathfrak{Z}_1 = \bar{z}_1 \bar{z}_2 \bar{z}_3$, $\mathfrak{Z}_2 = (z_1 \vee z_2)\, \bar{z}_3$ and $\mathfrak{Z}_3 = z_3$.

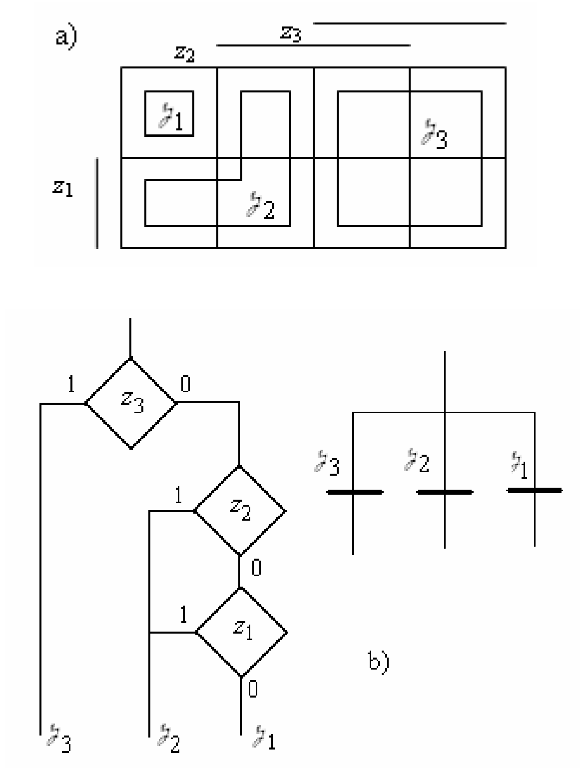

Fig. 4 Decomposition of set Z
a) in the Karnaugh map
b) corresponding Boolean expressions

Let us show how the nondeterminism of CA. can be avoided. It is just sufficient when for the system A, which is in the state s, CA is to accept the failure z_i or z_i $(z_i \neq z_j\,, i \neq j)$, so that
$x_i = \lambda_Z(s, z_i)$ and $x_j = \lambda_Z(s, z_j)$.

4. LOGIC CONTROL

It is evident that control technological devices are not dynamic systems but are potentially dynamic (they cannot be considered as systems). The result of identifying such the mentioned apparatus, however, is a dynamic system – *SALC* – formed by the controlled device and a subject, which, nolens volens, identified itself with the control automaton of the apparatus, *á propos.* a subject would hardly identify a conceptually controlled device without mentally controlling it.

Thus we deal with a model of the given *SALC* (Fig. 3).

$$SALC = \langle U \times [Z], S, \delta \rangle \qquad (10)$$

where U, Z, S are the respective failure and state alphabets given by the operator and δ is the transition relation, spec. function.

$$\delta : S \times U \times S : \langle s, u, s' \rangle, \qquad (11)$$

spec.

$$\delta : S \times U \times [2^{Z}] \to S : \{\delta, u, [z]\} \to s' \qquad (12)$$

so that $\delta \bigcup_{s'} (s, u, z) \Rightarrow \bigcup_{s'} z = Z$, where $\mathcal{Z}$ is the total decomposition to Z $(z \in \mathcal{Z},\ \mathcal{Z} \subseteq 2^{Z})$ and $[2^{Z}] = 2^{Z} / \{e\}$, $[z] = z/e$.

Let the searched for model of the statistic system CA be a finite automaton

$$CA = \langle U \times [Z],\ X,\ \lambda \rangle \qquad (13)$$

where X is the alphabet of "machine" control and λ is the assumed output function.

$$\lambda : S \times U \times [2^{Z}] \to X : \langle s, u, [z] \rangle \to x \qquad (14)$$

A model, though not much interesting, of a potentially dynamic technological device A is the ordered triad

$$A = \langle X \times [Z], S, \boldsymbol{d} \rangle \qquad (15)$$

where $\boldsymbol{d}$ is ¨the assumed input-output relation the

$$\boldsymbol{d} : X \times [2^{Z}] \times S : \{x, [z], \delta\}, \qquad (16)$$

but not a finite automaton since A is not a dynamic , and therefore not a static system either.

From the morphology of *SALC* the validity **of fundamental equality** of the automatic logical control can be derived

$$\delta = \lambda \circ \boldsymbol{d}\ ,$$

and the hypothesis concerning the form of the function λ and relation $\boldsymbol{d}$ is verified.
In other words

$$S \times U \times S = \left(S \times U \xrightarrow{\ \lambda\ } X \right) \circ \left(X \times S \right) \qquad (17)$$

spec.

$$\left(S \times U \times \left[2^{Z}\right] \xrightarrow{\ \delta\ } S \right) = \left(S \times U \times \left[2^{Z}\right] \xrightarrow{\ \delta\ } S \right) \circ$$

$$\circ \left(X \times \left[2^{Z}\right] \times S \right),$$

which is in accordance with the assumed form of λ and $\boldsymbol{d}$.

For easier design of CA. or its output function λ, it is advisable to include the ”machine” control x into the notation of the transition δ relation, spec. function *SALC* “machine” control of input x.

Example 2.: A truck (v) moves between points Z and K. An empty truck goes from point Z to point K; in the moment of arrival, the truck is loaded (w) by opening a filling hopper (n) – Fig. 5. When the loading of the truck is finished and the rated weight reached, the hopper is closed ant the truck returns to point Z. Then the alphabet of the “operator” control is $U = \{\text{start}, \text{stop}\}$, the alphabet of the “machine” control is $X = \{r, n, l, stand\}$, where r / l means that the truck will go to the right/left direction, n denotes that the truck will take load and the state alphabet is $S = \{z, \bar{z}\} \times \{k, \bar{k}\} \times \{v, w\}$, where $z/\bar{z}$ or $k/\bar{k}$ means on/off switching of the truck drive in the respective points Z and K, and v/w notifies that the truck is empty/loaded, respectively. Hence the tables: the transition table SALC of the truck (Tab. 1. a)), the output table of the truck *CA* (Tab. 1. b)), and the input-output table of the truck (Tab. 1. c)).

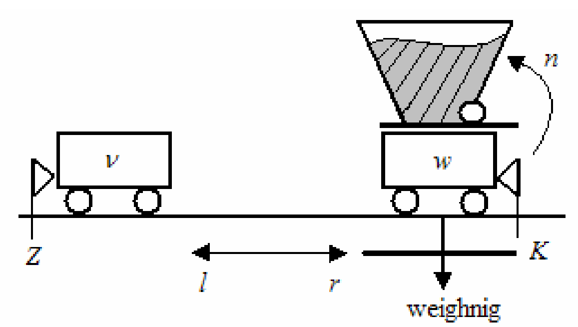

Fig. 5 Loading of the truck.

Tab. 1 a) transition table of the automatic logic control system of the truck,
b) response table of control automaton of the truck,
c) input-output table of the truck.

a)

	s'				
	ux	start			stop
σ	s	r	n	l	$stand$
1	$z\bar{k}v$	$\bar{z}\bar{k}v$			$z\bar{k}v$
2	$\bar{z}\bar{k}v$	$\bar{z}kv$			$\bar{z}\bar{k}v$
3	$\bar{z}kv$		$\bar{z}kw$		$\bar{z}kw$
4	$\bar{z}kw$			$\bar{z}\bar{k}w$	$\bar{z}kw$
5	$\bar{z}\bar{k}w$			$z\bar{k}w$	$\bar{z}\bar{k}w$
6	$z\bar{k}w$			$z\bar{k}w$	$z\bar{k}w$

b)

u	start			stop
σ	1, 2	3	4, 5, 6	1,2,4,5,6
x	r	n	l	$stand$

c)

x	r	n	l	$stand$
σ	1, 2	3	4, 5, 6	1,2,4,5,6

5. CONCLUSION

The paper does not deal with feedforward program control, even if the conception model of the program *CA* will be set up on *CA* with a failure input, whereas a feedback *CA* can do without a failure input

Controlling a dynamic system in a feedback way is redundant since the feedforward control directive with respect to “commanding” control of u will do. Technological devices, however, are not dynamic, but only if technologists, not cooperating with designers of control automation, do not provide them with *CA;* in that case the technological apparatus together with *CA* is a dynamic system – *SALC*, in which individual state trajectories are selected by the operator through the “command” control of u.

CA is a static system, i.e. it is a minimal one, with respect to the number of states. Is it the Glushkov *CA* of Mealy type, not the Glushkov nonminimal *CA* [5, 10, 13].

The authors believe that the paper provides a convincing, integrated state conception of the dynamic system and the system of automatic logical control.

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BIOGRAPHIES

Josef Bokr was born on 1940. In 1965 he graduated with honour at Moscow Power Institute with specialisation in mathematical computing device and apparatus. He received Ph.D. (CSc) degree with a thesis Logic Control in 1990 and was done an associate professor. He is working as a lecture of the Department of Informatics and Computer Sciences at West Bohemia University. His scientific research is focused on logic control and automata theory.

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