Alternation Models of Information use for Activity

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***Abstract*—This article explores models of information use for activity, highlighting the role of information in typical activities. It proposes that altering activity is the primary mechanism through which information is used. Three types of models are presented as essential for researching these alterations: Models of information delivery: These models address questions about the message delivered, the information added to the state of a specific activity, and the nature of the information itself; Models of changes in activity: These models focus on understanding what changes occur as a result of information received, how these changes manifest, and the reasons behind them; Models of changed activity fulfillment: These models address questions about how changes in activity are realized and how the results of the altered activity align with evolving demands. Examples of such models are provided, including diagrammatic, algebraic, and measure-theoretic models. These models are expected to pave the way for future research, potentially leading to the development of a contemporary theory of information application for activity, with implications for various fields, including business informatics, applied informatics, cybernetics, and organizational theory.**

I. Introduction

Information use for activity mathematical modeling is required to solve many practical problems. Among them are business informatics problems, applied informatics problems, and digital transformation problems. A common feature of these problems is that they raise questions about the results of information use in practice. Such questions can be: 'What information is needed to carry out activity successfully', 'How much information should be processed for activity to bring the best possible results,' and 'What characteristics of information processing should be achieved to achieve good enough activity quality?' The answers to such questions are preferable to be obtained using some kinds of mathematical models, which allows obtaining predictions of future results based on characteristics of activity and information technologies used for this activity fulfillment. Such predictions are possible to obtain based on mathematical models, which reflect stable (during activity) quantitative dependencies of information processing and activity, cause-and-effects relationships, and peculiarities appearing when information is used. But to obtain and use such mathematical models, it is needed to describe processes of information use and activity results formation depending on the information used and its processing characteristics. Unfortunately, this has not yet been done on a sufficient scale and in sufficient detail, at least in application areas such as information use for production and business processes, when modeling should reflect changing conditions during business and production processes. The reason, as our previous research shows [1], [2] is the conceptual and methodological difficulties that arise when the role of information is considered in activity under changing conditions. For example, the operation of the production system may require a quantitative estimation of the effect information obtained from the system environment during the operation of the system may have on the results of the operation of the system. Such data may be required to be estimated as functional dependence of the results of functioning against variables of information operations and information technologies use according to the plan of system functioning with appropriate information technology used. Such estimation results can be used to choose the best plan depending on the predicted operating conditions.

Such tasks may be realized, for example, when sustainable system functioning plans are developed or agile system functioning designed [3] to suit changing environmental conditions as a result of applied information technologies [4]. One of the distinguishing features of such tasks is information obtained using some kind of action designed for information exchange or information operation (information action) as the part of system functioning process and obtained as a result of information use to alter system functioning depending on information obtained.

To model such an information application, various models are required. Among them, the model of information action, i.e., action which goal is to obtain and/or transmit information.

II. Role of Information in the Activity Changes

I understood information as a change in data, description, reflection, or model of something that makes a difference (that is, a difference that makes a difference – [5], [6]). Making a difference is understood in this paper as making a difference in subject (actor, agent) activity. This difference in activity is hard to model and that is why it is the source of difficulties in modeling. Thus, when we say about information received, it means message received of such quality that it caused changes in activity. Information action result is information transmitted or obtained and so, activity changed. It is urgent to note that reflection or model of some kind shall be part of at least final state of information action. In most cases, information (let it be designated as ie_1) is obtained from objects in the environment through the system border with the use of some information action (let it be designated ia_1), performed by the system on its

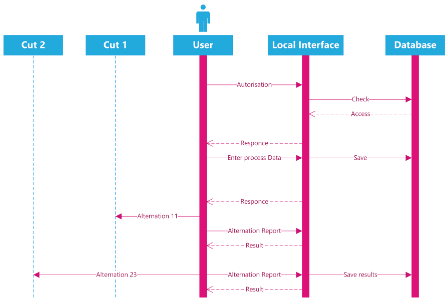

Fig. 1. Communication Diagram of message delivery to alternate activity network

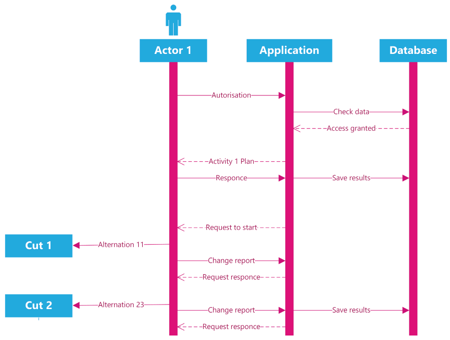

Fig. 2. New Diagram kind of message delivery to alternate activity network

border. The result of such action is reflected in some complex state cs_k within the system, such as $i_1 \in cs_k$. Complex state information substate may be represented with various formalisms, depending on reflected features. For example, this can be integral / differential equations. In the paper I consider activity model [6] in the form of action network [7]. So information use shall be modelled as changes to action network incurred by information delivered and results of such changes.

To model information use, three types of models shall be elaborated:

- Model of information message delivery to some parts of action network (what message delivered where and which state obtained as a result).
- Model of changes in action network (what changed, how it changed and why).
- Model of changed action network fulfillment results (how changes fulfilled and how results correspond to changing demands).

III. Model of information message delivery to some parts of action network

These models shall answer on questions: what message delivered where and which state obtained as a result.

I propose using Sequence Diagrams or UML communication/collaboration diagrams in conjunction with models of activity network parts, affected by signals in these diagrams. Other ways to build a model of information message delivery to some parts of action network can be suggested, but existing diagrams use allow integrating other diagrams, such as UML standard diagrams.

For example, as in Figure 1, if cuts of the network in a given moment modelled as parts of activity network alternated with use of software modelled, the communication diagram shall include appropriate objects $(Cut_1, Cut_2 ...., Cut_i)$ in the top of lifeline. In the Figure 2 other way of information message delivery to some parts of action network suggested. In this alternative, diagramming way parts of networks shown in separate (timed) dimension. To implement such diagrams, though, UML standard should be, possibly, changed to reflect parts of activity networks for sending signals to. Instead of cuts, other parts of activity networks can be used as changed objects. Let us consider what this change looks like and how it can be modelled on the example of changing various parts of the activity network.

IV. Model of changes in action network

Once information delivered and complex state, corresponding to action network part, changed, action network itself shall be changed. Let us consider some variants of changes.

A. *Elementary Local Change of the Single Action in Network*

Let us consider the elementary local change of a simple action network. One action changed. It is action 2 in the Figure 3 (shown with doubled circle). The dotted arrow shows the case of the information arrival. It modelled by information message delivery model. The cause of the change is information obtained in the state $s_(2b)$ of activity a_2 beginning. This can be information about system or environment changes, changed instructions, prescriptions, requirements for performing activity. Such information is the cause of further changes. Humans may perceive change in state through obtained information only. If we model change, then it means we knew such kind of change is possible before modelling. If it were possible, and we now know it happened now — then information about such possible event realization obtained. As well, a new event which was not predicted may happen. In this case, we can not model it explicitly, but it is possible to represent it as “known unknown” type of outcome — with unknown cause-effect relationships following such type of events which can be represented before actual change of state and activity (in material world) happens. We may deem such information as elementary in the sense it affects only one state of activity beginning. Elementary information causes a ’direct’ or first-order change in one complex state before appropriate action (a_2) starts. This change is simply information, recorded in a complex state. The complex state is the state which has information part.

Next, activity a_2, changed due to its initial state changed, may cause ”next-order changes”. “Second-order changes” are changes in further actions, following action changed due to partial order realization of activities. Such ”second order” changes in following actions can be applied by some kind

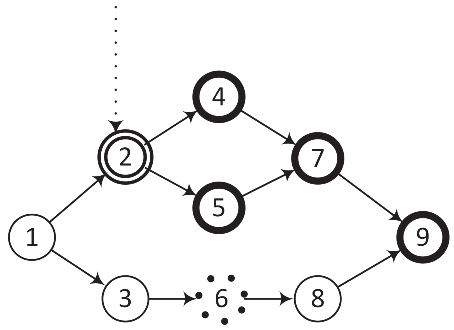

Fig. 3. Alternations as a result of single action changes

of propagation algorithm. Its results shown by bold circled actions in the network (a_4, a_5, a_7, a_9).

Kind of ”second order” changes can be modeled by cause-effect relationships. In figure 3, it is assumed there is cause-and effect relation between a_2 and a_6. It is determined through common equipment used to perform appropriate actions.

These changes’ propagation shall touch all states following in partial order relations logical structure of activities flow in network, because these activities always connected by activities time to start dependencies in chains, but may change other states (not in transitional closure of order relations) as well — if they connected by cause-effect relations, for example. In many cases, other “next order changes” possible as well.

Such “next order changes” may cause “waterfall” of following changes propagation due to elementary change in action may cause resulting activity states changes and realization of next appropriate state/activity changes not just through further activities changes, but through further propagation of cause-and-effect relationships following activity changes.

Thus, elementary information may bring a set of changes not to the elementary activity only, but to other states/activities: following for such activity in partial order or connected with cause-and-effect relationships.

B. Information Action in Network of Actions

Information obtained in the state of action beginning shall have some source, and it shall be obtained due to some (information) action (s).

Information action result is information transmitted or obtained and so, this information or data about it, its reflection or model of some kind shall be part of at least final state of information action. An example schema for obtaining information is shown in Figure 4. In most cases, information ie_1 obtained from objects in environment through border of the system with use of some information action (I will designate it ia_1), for example – performed by the system on its border as in the Figure 8. The result of such action reflected in some complex state cs_k inside the system, such as $i_1 \in cs_k$. Complex state information substate may be represented with various formalisms, depending on reflected features. For example, this can be integral / differential equations and in this case the

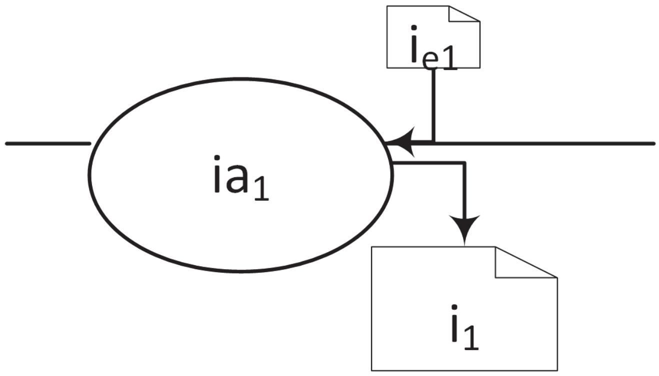

Fig. 4. Result of information obtained as a reflection kind

schema in the Figure 8 will represent a kind of hybrid automata [8], acting over the model of the system.

In the case considered before as elementary local change, cs_k is the state of action a_2, changed due to information I_1, beginning. Let us name this type of complex states as type 1 states. Information from outside or inside of system boundaries updates only one state of action in the network.

C. Complex Change of the Set of Actions, performed within an elementary interval of time in Network

In general, changes can be more complex and may change a set of actions, performed at various moments, affect a set of states, and incur a set of messages to provide information.

The particular kind of changes incurred depends on the states that changed (states of which objects, subjects, and actions are affected by changes), the kind of information, kind of changes and the kind of change results, as well as propagation details of those results.

Let us consider the case, when represented activities performed in certain short intervals of time affected. We will determine this interval as the timeframe, when certain minimal cut of the action network may be realized. Cut of the action network is the concept derived from the traditional network cut concept: the set of vertices that separate two parts of the network from each other, making them not connected. Activity network vertices are actions, and so it differs in that time is associated with vertices. Minimal cut of activity network is cut which can not be smaller for this network. Such minimal cuts are associated with sets of actions, which can be performed together, within a short, possibly infinitesimal timeframe within the minimal cut timeframe.

Thus, if certain information became available at the given moment, we may consider actions which fulfilled in time interval such as the moment mentioned sticking inside time interval defined for actions affected by change.

If the action network cut is used as a set of such actions [9], it guarantees that no other actions may be performed in the selected time frame (for these actions). This can be used to determine actions, which are suspicious for change in certain circumstances. Exactly, if information obtained may directly

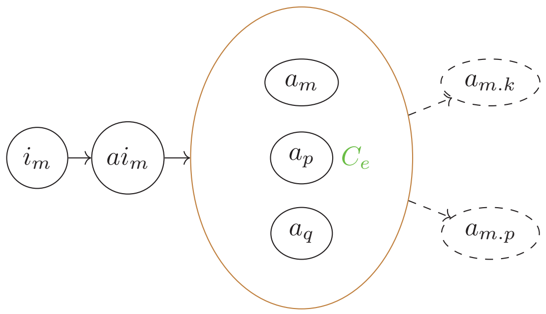

Fig. 5. Type 2 case of actions alternation: A few actions of the one cut affected

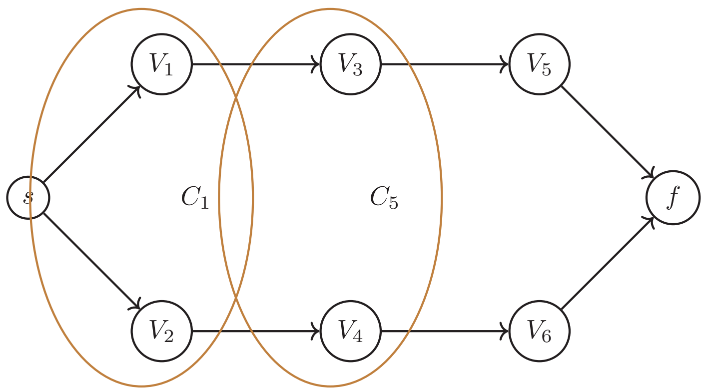

Fig. 6. Network with 2 cuts

change current actions only, but not future ones, then future actions can be modelled as changed indirectly and updated through propagation mechanisms.

Let us name this type of complex states as type 2 states for alternation. Information from outside of system boundaries updates sets (cuts) of actions states in the network, such as these actions fulfilled in certain (very short or even infinitesimal) time interval. Example of such actions updated shown in Figure IV-C. Actions a_m, a_p, a_q affected by information received during appropriate cut of the network C_e fulfillment. In general, a few cuts can be possible in any given moment. Example of such situation shown in the Figure IV-C. In the Figure IV-C N_0- a network given and information i can be directed to any set of N_0 vertices fulfilled in a given moment - variable cut C_i. Once information i obtained by jobs associated with cut C_i, all jobs which follow jobs, associated with cut C_i (jobs of subnetwork N_i) may be affected by information i.

D. A single information event caused change in a variety of possible sets of dependent activity nodes

A variety of possible sets of activities can be represented as a tree of possible fragments initiated by given cuts in the network.

Each fragment defined as subnetwork, obtained on vertices of the initial network, such as these vertices follow the given cut. Thus, each network cut produces a fragment (right fragment) and rest of the network part of the network before cut (or: left fragment). By other words, each cut cuts the network in two fragments – left and right ones.

Right fragment corresponds to part of network, which planned to be performed in the future. Thus, information obtained at the moment when given cut fulfilled, may affect only vertices from the right fragment but not from the left one.

I suggest a tree of possible cuts, and so — tree of possible right fragments of the network. It is shown in Figure. Each branch of the tree corresponds to a possible set of activities started with possible cuts.

In the Figure, $N_1(C_1)-$ network fragment which starts with cut $C_1 = \{V_1, V_2\}$, where $\{V_1, V_2\}$ are associated with network vertices, changed in the first place by information obtained and causing change in subnetwork $N_1(C_1)$ of vertices starting with C_1 vertices; $N_5(C_5)-$ network fragment which starts with cut $C_5 = \{V_4, V_3\}$; Cuts C_1, C_5 were shown in the Figure IV-C as part of the network.

Tree model suggested describes altering of network's right fragments depending on information arrival cases. These cases determined by cuts of the networks and by information obtained while cut is fulfilled:

$$Fr(C_i, I(C_i)) = f(C_i, I(C_i)), \tag{1}$$

where

$f-$ function of right fragments. Can be given in the form of tables, as in I. II.

C_i-minimal cut of the network in the $i-$th possible interval of time since network started to be fulfilled;

$Fr-$fragment of the network, which follows current (alternated) network after $I(C_i)-$ message (information) which change subject preferences as of activity performed.

In this paper, preferences changed are goals $G_1, ...G_i, ...G_k$ and requirements to results of activity performed, according to these goals.

The sequence of cuts $C_0...C_i...C_9$ of the network N_0 defines possible alternations of goals in time, as it is described in Figure 7 and Table I.

Function $f(C_i, I(C_i))$ maps this possible alternations of goals into possible alternated networks, as it is described in the Figure I.

Depending on message received, cut realized and on other possible information $I(C_i)$ obtained by subject (agent. actor), depending on environment conditions and subject states once message defining information $I(C_i)$ arrived new goal can be perceived by subject and so new network of operations will be further realized by it.

To model such changes, reflective modelling required, i.e., modeling of subject and its relations changes.

Let such model build in the simplest tabular function form such as each message m_i arrived under condition of cut C_i realized led to information i obtained and corresponding change of possibility of further operations' fulfillment in order to perceive one of goals (which incoming message information is related to).

As such, the table shows a reflective model of subject (agent, actor) behavior under conditions of information use

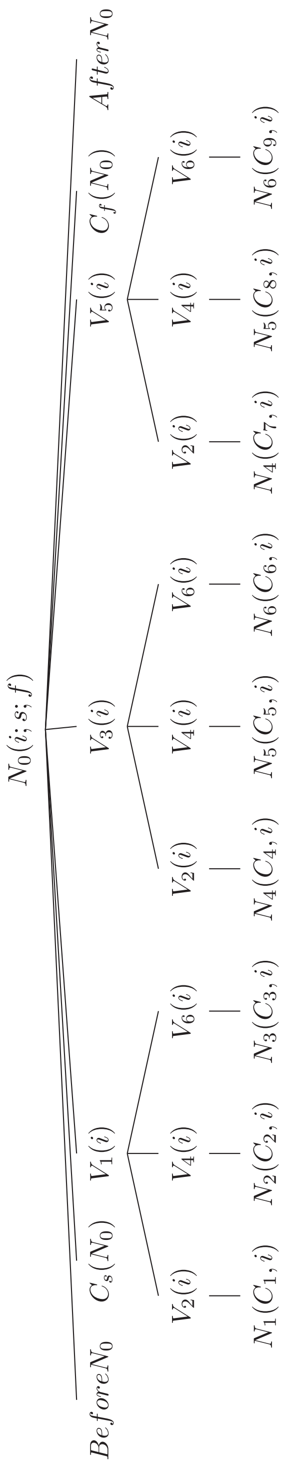

Fig. 7. Tree of possible cuts of the network

for determining course of future actions as it was described earlier in [10].

Such a reflective model of changes is just one of possible reflective models, which reflects changes of operational situation for subject and its reaction to such a change.

Other ones are, for example, models that depict changes in possibilities of subjects in order to perform its operations with certain characteristics, or changed risks, associated with actions.

These reflective models reflect other features comparatively to the reflective models of changes in goals of activity under various circumstances already considered.

Among these features are possibilities to perform changes. One of reflective models of changes of possibilities to perform activity, shown in Table II.

In the Table II possible networks defined as function of message, cut, and goal. In this particular case, the function defined by expert in tabular form and only part of the table shown as an example.

Possible networks formation [11] is the result of activity reflective modelling in the view of possibilities. The networks listed can be further specified [12] in terms of operations parameters and variables specifying various particular techniques to perform each operation.

Such models can be referred to as reflective models of activity possibilities [13].

Finally, activity is performed to achieve the needed results [14]. The model of results correspondence to requirements is a reflective model of activity, which makes it possible to judge how good such activity is.

Thus, three types of reflective models shall be built. They are:

- Reflective models of information use for determining course of future actions (predictive reflection).
- Reflective models of activity possibilities (possibilities reflection).
- Reflective models of activity result in correspondence to changing demands (results correspondence reflection).

These reflective models shall allow one to predict results of each consecutive plan of activity possible, parsing and estimating all such possible plans of activity built, and building measures of correspondence of projected activity results to possible demands. This shall allow for making a decision about the best possible alternative based on projective estimation of the measure of correspondence for each alternative.

However, such way to react with change on message obtained is not only one way possible to use information. The way to react considered was related to the construction of the set of probable reactions and evaluation of each possible reaction with special measure constructed.

Other ways to react are:

- Deciding among a set of smaller operations, which organized into activity.
- Using rules (possibly informal) to react to messages;
- Changing relations, which are used to organize a whole activity from its parts and their behavior.

TABLE I
TABULAR MODEL OF POSSIBLE NETWORKS FRAGMENTS ALTERNATIONS AFTER CUTS 1-6

Message	Network Cut realized.	Goal/Requirements Id	Network Fragment	Actualization Prob.	Effects correspondence probability
M_i	C_1	G_1	$N(11)(C_1)$	0.1	0.71
M_i	C_1	G_2	$N(12)(C_1)$	0.7	0.43
M_i	C_1	G_3	$N(13)(C_1)$	0.2	0.87
M_i	C_2	G_1	$N(21)(C_1)$	0.1	0.99
M_i	C_2	G_2	$N(22)(C_2)$	0.7	0.97
M_i	C_2	G_3	$N(23)(C_2)$	0.2	0.67
M_i	C_3	G_1	$N(31)(C_3)$	0.1	0.57
M_i	C_3	G_2	$N(32)(C_3)$	0.7	0.21
M_i	C_3	G_3	$N(33)(C_3)$	0.2	0.17
M_i	C_4	G_1	$N(41)(C_4)$	0.1	0.11
M_i	C_4	G_2	$N(42)(C_4)$	0.7	0.47
M_i	C_4	G_3	$N(43)(C_4)$	0.2	0.85
M_i	C_5	G_1	$N(51)(C_5)$	0.4	0.41
M_i	C_5	G_2	$N(52)(C_5)$	0.6	0.44
M_i	C_5	G_3	$N(53)(C_5)$	0.0	NULL
M_i	C_6	G_1	$N(61)(C_6)$	0.0	NULL
M_i	C_6	G_2	$N(62)(C_6)$	0.9	0.73
M_i	C_6	G_3	$N(63)(C_6)$	0.1	0.16

TABLE II
TABULAR MODEL OF POSSIBLE ACTIVITY NETWORKS SEQUENCES

Message	Cut real.	Goal/Pref.	Possible further networks
M_k	C_1	G_1	$\{N_{11}, N_{12}, N_{13}, N_{14}, N_{15}\}$
M_l	C_1	G_2	$\{N_{17}, N_{18}, N_{19}, N_{120}, N_{121}\}$
M_m	C_1	G_3	$\{N_{18}, N_{19}, N_{120}, N_{124}, N_{125}\}$
M_n	C_2	G_1	$\{N_{19}, N_{121}, N_{123}, N_{124}, N_{125}\}$
M_o	C_2	G_2	$\{N_{16}, N_{122}, N_{123}, N_{124}, N_{125}\}$
M_p	C_2	G_3	$\{N_{15}, N_{122}, N_{123}, N_{124}, N_{125}\}$

- Organizing experiment to determine reaction on message received.
- Socializing to determine reaction on the received message based on the experience of another subject or decisions with the same message.
- Delegating the decision and / or reaction to other entities.
- Using metamodels (meta-information, meta-methods) to react on messages/information, including higher reflection levels models.
- Combinations of methods suggested, as well as their systematically constructed complexes.

E. Complex Change of the Set of Actions, performed at any future interval of time in Network

Let us name this type of complex states as type 3 complex states. Complex states of this type use information as follows:

- Initial complex states of this type first receive a copy of information for each initial complex state.
- Propagation algorithm fulfilled.
- Actions not affected by propagation added unchanged.
- Network constructed used as a result of complex change due to information obtained. It substitutes network before information obtained.

V. COMPLEX STATES OF ALTERNATED NETWORK TRANSITION SYSTEMS

Definition 1 (Transition System)**.** *A transition system is a triple* $(\Gamma, \hookrightarrow, T)$ *where* Γ *is a set of configurations,* $\rightarrow$ *is the transition relation, which is a subset of* $\Gamma \times \Gamma$*, and* $T \subseteq \Gamma$ *is a set of terminal configurations.*

Definition 2 (Complex States Transition System)**.** *Let* $\Gamma_i -$ *set of complex states of type* i*. Then, according to Definition 1 it spawns a transition system of complex states of the type* i*.*

- Let $\Gamma_1 -$ set of complex states of type 1. Such transition system along with update propagation mechanism (algorithm) defines networks, fulfilled as a result of type 1 information use.
- Let $\Gamma_2 -$ set of complex states of type 2. Then it spawns a transition system of type 2 states. Such transition system along with update propagation mechanism (algorithm) defines networks, fulfilled as a result of type 2 information use.
- Let $\Gamma_3 -$ set of complex states of type 1. Then it spawns a transition system of type 3 states. Such transition system along with update propagation mechanism (algorithm)

defines networks, fulfilled as a result of type 3 information use.

A. Complex Actions of Alternated Processes Calculus

An action calculus is specified by a set $\mathfrak{K}$ of controls, plus a reaction relation, which describes the interaction between control processes. Each control $\mathfrak{K} \in \mathbf{K}$ has an associated arity $((m1, n1), ..., (mr, nr)) \rightarrow (k, l)$, which informs us that a control process $\mathfrak{K}(P1, ..., Pr)$ has arity (k, l) such that Pi has arity (mi, ni).

Definition 3 (Action Calculus with Complex States)**.** *The set $P'AC(K)$ of pre-processes of an action calculus specified by control set $\mathfrak{K}$ is defined by the grammar:*

- $P ::= idm$ *Identity.*
- pm, n *Permutation.*
- $P|P$ *Parallel composition.*
- $P \cdot P$ *Application.*
- hxi *Datum*
- $(x)P$ *Abstraction*
- $\mathfrak{K}(P1, ..., Pr)$ *Control process.*

The set $\mathfrak{PAC}(\mathfrak{K})$ of action processes of arity (m, n), specified by control set $\mathfrak{K}$, is defined by the identity and permutation axioms:

- $idm : (m, m)$.
- $pm, n : (m + n, n + m)$.

the appropriate rules for definition 3 of Action Calculus with Complex States, and the control rule: control set $\mathfrak{K}$, is defined by the identity and permutation axioms:

- $P_i : (m_i, n_i)i \in \{1, ...r\}$.
- $\mathfrak{K}(P_1, ..., P_r) : (k, l)$. *control set $\mathfrak{K}$, is defined by the identity and permutation axioms:*

where control $\mathfrak{K}$ has the arity $((m_1, n_1), ...(m_r, n_r)) \hookrightarrow (k, l)$.

This definition formed in accordance with definitions of situations and state calculi [15] but for complex states.

As it was mentioned, "to make a difference" [5], [6]) information shall be supplied to one of the other actions in order to change the course of some of them. This can be done by assigning information to the substate of some initial state of the 'material' action. Appropriate information can be obtained with information action. "Material" action is action intended to produce change in energy or substance or their transmission. Thus, its (beginning or finish or other states) are not necessarily contains any information and action. Such complex states and actions (transitions) of various kind form sequences, which studied by complex state transition systems and process algebras on the complex states. For modelling information use, some states of the system functioning in transition systems and in process algebra shall be complex — i.e., as defined earlier, shall include information substates obtained due to reflections from another states (substates).

The example of such informational substate i_1 and so, complex state formation, is illustrated in Figure 8. It was obtained as a result of information action ia_1 outcomes i_1 and its further reflection in the complex state CS_1. We will name such states as complex states (CS_1). Complex states information substates contain reflected data, model, or description. That qualify models created with such complex states use as reflective. Under reflective model, I will define model which parts are reflected from some data / description or information. Complex states (CS_1) and models which are build based on it (transitions between complex states, sequences of complex states, networks of complex states, automata of complex states) are reflective models because they contain reflections of the other information substates, data, or descriptions. Such reflection's objective, among other, is creation of prescriptive information for actions.

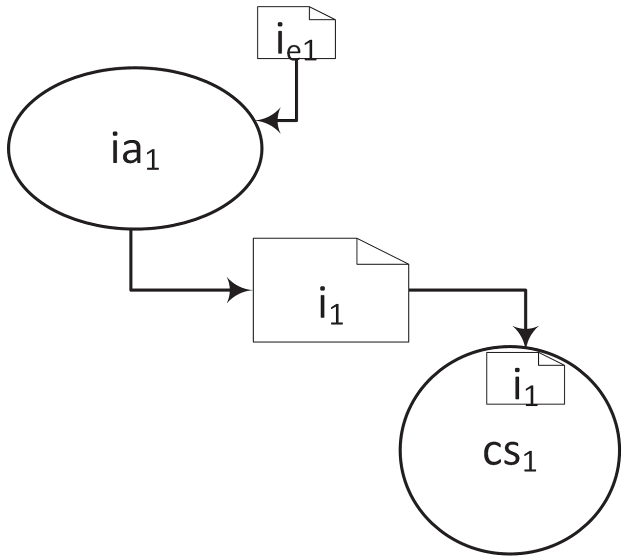

Fig. 8. Complex state creation as a result of information obtained

Described (cybernetic in its nature) process of alternation with use of information substates can be considered somehow analogues to live organism's role of information in sensorial, neural and reactive actions and life genesis [16]. Information obtained with use of some activities, then transferred, possibly using kinds of reflection, than used to produce reflection of usable kind and finally used by cause-effect relationship and outcome state changes as a result of this chain of reflections, transmissions, transformations, and use.

In case of artificial systems chains of information and material actions, chains of (complex) states and (information, material) actions are playing the role of chains of sensorial, neural and reactive actions.

As a result, reflective models — as it was previously discussed in [10] may be models of chains of: complex states, of information transmissions and of its use to alter material states. They are reflective because each consequent complex state caused by a previous state through some kind of reflection of previous states in the sequence.

Reflective models chains take forms of reflections chains and forms of further cause-and effect relationships and "material" states changes chains as a result of complex states realizations. This process of state changes chains due to reflective models realizations as chains of (complex) states shall be modeled with appropriate models of information application for activity. This application takes a dual form of information application and reflective models creation and use as a result of information obtained.

This process can be illustrated with analogies of live organisms, which can produce reactions on information obtained by them and whose main function is believed to be information preservation.

Information applicable by reflection and further creation of system complex states results in changes of cause-and-effect relationships and, as a result, in changes of “material” states. This change is performed by actions of humans or actions performed under their control but directed by information obtained and/or stored in complex states. This (prescriptive) information can be instructions, prescriptions, plans, and programs.

Reflective models of complex states and following them material states, resulted due to actions from complex states, can be viewed as models of information application. The network of all possible complex states during system functioning represent the model of system functioning under possible changes of conditions and appropriate information processing and use. New information obtained during functioning leads to changed complex states and, next, to changed material states through performed action, This process is reflection of information in practice. There is analogy of this process with organism’s genesis due to actions performed by organism according to genetic information. After information materialized, new information generated about results of information application, and it is combined in complex states of the new sequences of states and actions. Sequences of complex states and transitions, due to actions (information, material) form probabilistic partial ordered sets (or networks of actions) with information traces embedded into sequences of actions and states.

VI. Models of action networks fulfillment results correspondence to the demands

I am suggesting use of results already obtained in the theory of goal-directed processes efficiency and theory of system’s potential [17] for building models of changed action network fulfillment results. These models shall answer on questions: how changes fulfilled and how results correspond to changing demands.

Measures of efficiency, system potential (capability), and entropy to construct such models can be applied. The author examined measures of information application efficacy, efficiency, and their interplay with measures of information quality and entropy. Peculiarities, and available approaches for information application measures construction, were studied. Literature review was performed on the subject of IQ and the evaluation of decision qualities were conducted. Additionally, a survey of approaches for estimating measures of the value of information, concentrating on fundamental and mathematical methods, was presented in [18] and by numerous other researchers utilizing an empirical approach. As noted by Y. Lee, R. Wang, and D. Strong regarding this approach: “the disadvantage is that the correctness or completeness of the results cannot be proven via fundamental principles.” The fitness for use is explored by [19]. As highlighted by L. Floridi and P. Illari: “Qualitative descriptions of the meanings of words or phrases such as ‘information quality’ or ‘timeliness’ are not the same as formal metrics required to measure them, which are necessary for implementation” [20], [21].

The approach proposed in the article is based on construction of appropriate measures on mathematical models of sequences of complex states of information use for system activity. The suggested approach is based on concepts and formal models, suggested in [22]. The new measures proposed in my article were further elaborated based on probabilistic and entropy measures suggested earlier. These new measures are computed with mathematical models of information application and corresponding system potential measures. Such measures and mathematical models which elaborate them may allow solving various practical problems related to information application and digital transformation – as mathematical problems, for example, as operational research and mathematical programming problems. Graph-theoretic models, constructed based on the information application schemes for actions in systems suggested, form the basis for the proposed models. Probabilistic functional models were developed based on the constructed graph-theoretic models.

This approach is similar to the information process modeling approach suggested by C. Batini and M. Scannapieco in [23], but it has some deficiencies, as noted by the authors. They mention that: “it does not distinguish between or provide specific formalisms for operational processes that use elementary data and decision processes that use aggregated data” [23]. The main features of information processing are that, they inevitably lead to purposeful changes in action and to changes in interaction with the environment [24]. However, the mathematical models necessary to describe these changes in human activities are not available yet in known literature in the required quality. The situation can be changed by applying various approaches to describe changeable activity, such as the theory of functional systems [25], if it is described mathematically with appropriate formal means.

VII. Conclusions

The paper includes approach for modelling of information use for activity in systems. Models and methods presented are expected to pave the way for future research, potentially leading to the creation of a contemporary theory of information application for activity modelling, especially one, suited for formal, mathematical description of the creation of information use results and predicting the outcomes of information use with formal methods and models application. Approach suggested allows to build accurate, scientifically sound formal models of information application. Such models can be used to estimate efficiency, security, complexity of information application quantitatively. The key finding of this study is the concept and method to model information application for activity. Novelty of the approach is in suggested mathematical formalisms which allows building models of information application and further, to solve practical problems as corresponding mathematical problems. Author contributed concept of such modelling and key definitions of formal models suggested.

Material of the paper is based on formal metrics to measure concepts like ”information quality” and ”efficiency of information use”, suggested by the author, along with frameworks for their practical implementation in His previous works. Previous works of the author at FRUCT conference contain practical example of such properties' estimation. The future scope includes the development of the formalisms suggested and creation of the software platform for suggested formalisms construction and application. If these software platform and formalisms were to be established, they could be integrated into system and complexity science, theory of organization, cybernetics, and activity theories of various kind to construct models of information application and techniques for predicting results of information application. Consequently, researchers will be empowered to tackle a diverse range of issues associated with improving information use and deliberately modifying systems and their operations in response to changing conditions.

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