Development and Operations Modeling as Information Application in Cause-and-Effect Relations Chains

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***Abstract*—The article is dedicated to modeling development and operation processes as an application of information to the functioning of the system. The application of information is described as alternation of cause- and-effect-relations chains to the information applied. The objective is to develop a formal representation and predictive explanation of the application of information, to enable accurate predictions of the impact of information obtained with developed and deployed software and implicated in altered circumstances. The distinguishing feature of the suggested research results is the mathematical character of the developed models. The authors introduces the concept of a complex state as a state that encompasses reflections of information, along with graph-theoretic models of such states in the form of potential sequences of complex states and transitions. Models of information application were represented with complex state, ports, and their transitions under information flows conditions. Such transitions are proposed to model with automata on graphs formalisms. It is proposed to use models presented to construct measure spaces of information application for activity and to solve various information pragmatics models based on that. Authors presents a novel approach to addressing issues related to information application for activity on the example of DevOps planning problem and agile system design problem.**

I. Introduction

The article is dedicated to considering the problem of the application of information [1] for system functioning as a result of Development and Operations (DevOps) processes. We are focused on the conceptual and formal modeling, and definition of the problem of DevOps planning with the application of formal models developed.

The objective is to develop a formal representation of DevOps planning, and predictive explanation of information utilization, aiming to enable accurate predictions of the impact of information usage in altered circumstances, based on the utilization of mathematical models.

Information use mathematical modeling required to solve many problems of information application. For example, information application for production system functioning may require one to estimate quantitatively what effect information obtained from system environment during system functioning at one moment or another may have on system functioning effects depending on the variables of the plan of system functioning used. Such estimation results can be further used to choose better plan depending on environmental conditions. Such tasks appear, for example, when plans of sustainable system functioning developed or agile system functioning designed to suite changing environmental conditions. One of the distinguishing features of such tasks is information obtained using some kind of action designed for information exchange or information produce (information action) as part of system functioning process and obtained as a result of information use to alter system functioning depending on information obtained. To model such information application, various models required. Among them, model of information action, i.e., action which goal is to obtain and/or transmit information. Information in article understood as change in data, description, reflection, or — in short, "reflection of something which makes a difference" (compare with difference which makes a difference [1]). 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.

Such complex state reflects information obtained, but may become the cause of changes in other states, including "material" states, i.e., states which are not intended for information transmission/elaboration but for energy and matter transmission in time or/and space. The mechanism of such information use ("materialization") is through use of actions which defined, among other things, with information. Examples of such information which alter course of actions are instructions, manuals, specifications, route maps and this is information obtained as reflection of other information available for the system. Such information used during actions of humans or artificial objects (agents, robots) created by humans for performing activities. During such activities, according to information reflected, individual actions and their sets (sequences) altered depending on information obtained. Information in such actions used in cause-and effect relations, determined by actions details, which can be altered depending on human, agent, or robot choice. This choice and, so, cause-and-effect relations realized depends on information reflected and elaborated by the system. In this respect, we may say that reflected information can be "materialized back" through actions. Humans mind and artificial objects (agents, robots) created by them, as a result, deemed as two-way bridges between "reflected" and "reflected back". So, as a result, material world "reflected back" through activities and by application of information previously reflected by the humans or objects created by them for the purpose. These "bridges" can be formalized with possible routes through them and through their possible sequences characteristics (including probabilities structures and material effects characteristics structures). Through this research possibility, one may try to understand and evaluate results of information and information technologies applied for system functioning. It is needed to note the eternal analogy of such sequences "through bridges" and the ways live matter acts apart from human beings and artificial objects created by humans for activities. This analogy shall be understood through further cybernetic and system theoretic researches.

The article contains concept and structural (graph theoretic) models of information application for system functioning ("bridges" mentioned, formalized as routes in the routes in possible complex states trees). Further, this routes and trees serve as the basis to develop functional models of information application for action in systems. They, in turn, allows defining various kinds of formal problem's of information application for actions in systems definition.

Models and methods obtained allow to solve many practical problems of information application in various kinds of systems as mathematical problems and to automate such problems decisions using modern digital computer technologies.

II. The Concept of Complex States for Information Receipt, Reflection, and Application

Example schema of obtaining information shown in Fig. 1. In most cases, information ie_1 obtained from objects in environment through border of the system with use of some information action ia_1, performed by the system on its border. 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 schema in Fig. 1 will represent a kind of hybrid automata [2], acting over the model of the system.

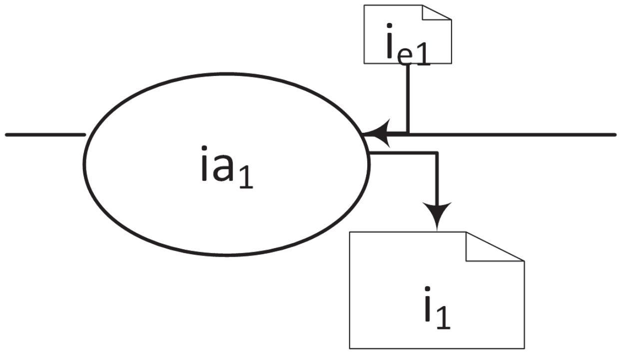

Fig. 1. Result of information obtained as a reflection kind

Further, "to make a difference" [1] 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 substate of some initial state of the "material" 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.

As a result, to model information use, some states of actions of the system functioning shall include information substates obtained due to reflections from another states (substates). The example of such informational substate i_1 is illustrated in Fig. 2. It obtained as a result of information action ia_1 outcomes i_1 and its further reflection in 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. In Fig. 3 action ma_1 uses prescription information i_1 of complex state information substate for performing changed (according to reflected information i_1) "material" action. Information substates of complex states can reflect prescriptive information obtained as a result of information state transmission/transformation/elaboration with some information action. For example, information substates can be constructed from instruction manuals for action or with other information, which may result in cause-and-effect relationships realization and actual change in final "material" states of appropriate actions performed. Then, other states following after final state of activity, changed by complex state, can be affected and effects of the functioning as a whole changed.

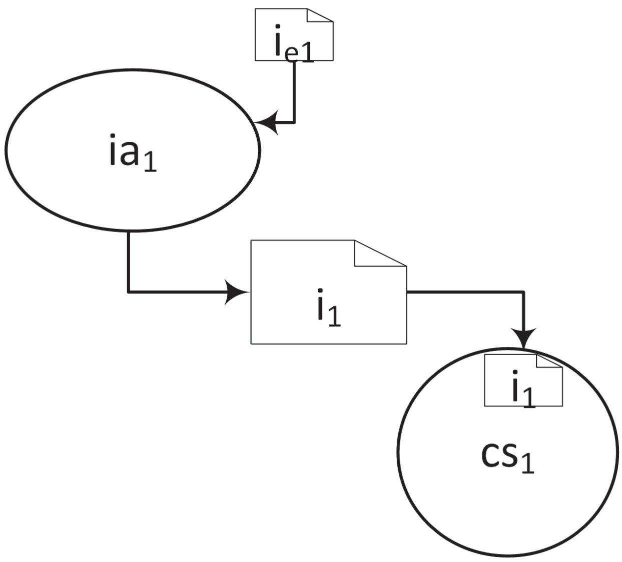

Fig. 2. Complex state creation as a result of information obtained

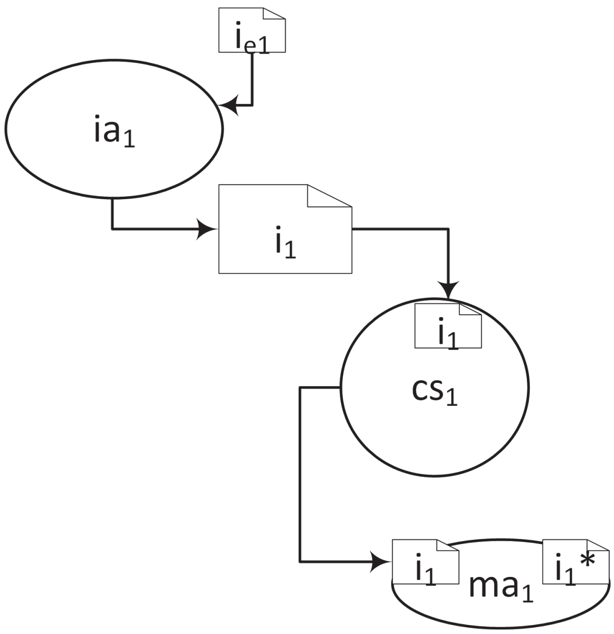

Fig. 3. Starting action based on prescriptive information i_1 in complex state CS_1, associated with action beginning

As a result, chains of complex states changes sequences formed, which can be modelled with various kinds of reflective models. The one of simplest model of this kind illustrated in Fig. 4. Two complex states CS_1 and CS_1^* shown, first one is associated with action beginning and second one — with action end (final state). (CS_1, CS_1^*) pair corresponds to a reflective model of transition between states, caused by appropriate action. Final information substate i_1 reflected back to information action ia_1 for new processing and updated information i_1' reflection.

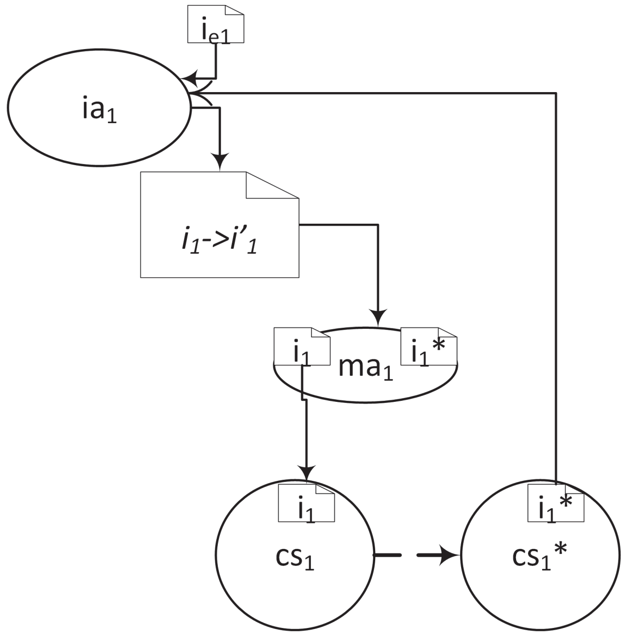

Fig. 4. Sequences of complex states

This process can be considered somehow analogues to live organism's role of information in sensorial, neural and reactive actions and life genesis [3]. 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 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 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 which 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 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.

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.

III. Algebraic structures for Cause-And-Effect Relations and Information Application Modeling

As it was shown above, models of information application can be represented as the set of possible partially ordered sets (POSET's). Each set elements are states, and partial order between states defined as formalization of a one of a kind CER. Each of POSET's is defined by particular case of CER realization. Depending on information obtained/used and events in environment happened CER realization cases can be different. Still, only one CER case can be realised (a posteriori) but many of cases possible (a priori). The set of all possible POSETs can be represented as appropriate algebraic structure.

It is worth to notice that each POSET represents particular case of states changes, realized a posteriori. States can be represented as complex states, as it was mentioned before. As a result of such representation only one state can be realised in each fixed moment (but multiple complex states possible in the same moment a priori). Thus, each case of CER realization can be represented as perfectly ordered set of (probably, complex) states - chains of states.

The structure of possible states can be given with a tree-like graphical model of possible states as in Fig. 1 d). In many cases complex states in sequences can be made mutually exclusive as different non overlapping cuts of POSETs [4]. In this case chains of states representing cases of CER realization a posteriori are non overlapping. We will name the set of such sequences, representing all possible sequences of CER realization in various conditions, as set $\mathfrak{Ds}$ of dependent states sequences. Each $\mathfrak{Ds}$ depends on system $\mathfrak{S}$ and activities $\mathfrak{A}(\mathfrak{S})$ it performs structure $\mathfrak{St}(\mathfrak{A},\mathfrak{S})$ and characteristics $\mathfrak{Ch}(\mathfrak{St},\mathfrak{A},\mathfrak{S})$, because CER depends on these structure and characteristics. As well, it depends on information $\mathfrak{I}(t)$ available at each moment t and on other conditions $\mathfrak{Co}(t)$ at this moment. Among conditions are states of nature, states of humans knowledge, preferences, and goals. Thus,

$$\mathfrak{Ds} = A(St, \mathfrak{S}, \mathfrak{A}, \mathfrak{Ch}, \mathfrak{I}, \mathfrak{Co}, t) \tag{1}$$

Appropriate set of independent states sets $\overline{\mathfrak{Ds}}$ can be built for each set of dependent states sequences. For example, as their cuts.

Algorithms A of $\mathfrak{DS}$ construction can be obtained as a result of information application modeling. Such modeling requires analysis of multiple sources of information, such as instructions, manuals, textbooks, and articles which describe possible variety of CER and their change in various circumstances under varied information.

For example, such algorithms can be created on the base of discrete automata formalisms and action/state languages [5].

Further, analysis of information application required. Its result shall be functional dependencies which allow us to compute indicators of activity quality given information which was used to perform this activity in certain circumstances:

$$\mathfrak{F}_{\mathfrak{D}}\mathfrak{s} = \{F(St, \mathfrak{S}, \mathfrak{A}, \mathfrak{Ch}, \mathfrak{I}, \mathfrak{Co}, t)\} \tag{2}$$

Knowledge of the function set $\mathfrak{F}_{\mathfrak{D}}\mathfrak{s}$ allows to evaluate quality measures $\mathfrak{Q}_{\mathfrak{D}}\mathfrak{s}$ of information application for system functioning depending system, activity, information, and conditions over time and further, to solve various problems of information application.

Among such measures are system potential and information technology potential measure [6]. Once measures of information use quality evaluated quantitatively, it makes possible to solve various problems of information application in systems.

Such problems (Among them, problem of DevOps planning) can be represented as problem of information application for system functioning planning. Its general formal problem statement may look as follows:

$$\pi^* = \mathbf{ArgMax}\{\mathfrak{Q}_{\mathfrak{D}}\mathfrak{s}(\mathfrak{S}, \mathfrak{A}, \mathfrak{Ch}, \mathfrak{I}, \mathfrak{Co}, t))\}, \\ < \mathfrak{S}, \mathfrak{A}, \mathfrak{Ch}, \mathfrak{I}, \mathfrak{Co} > \in \mathfrak{P}, t \in \mathfrak{T}. \tag{3}$$

Equations 1–3 allows to solve various problems of information application model building, problem analysis, plan synthesis. Among such problems of Information modeling in DevOps, DevOps problem analysis and DevOps plans synthesis.

Such problems are related to cases, when information subsystem can be upgraded during system functioning in variable conditions – due to its modernization. Appropriate modeling, analysis and planning problems arise as a result.

Among other problems of the kind specified are, for example, problems of agile systems design for various circumstances and various information technologies used.

IV. Approach to Formulation of Problems of Information Application for System Functioning

The author examined measures of information application efficacy, efficiency, and their interplay with measures of information quality. 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 [7] 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 [8]. 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" [9], [10].

The approach proposed in the article is based on a mathematical modeling of sequences of reflective complex states of information use for system activity. The suggested approach is based on concepts and formal models, suggested in [4]. The new measures proposed in [6] 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 [11], 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" [11]. The main features of information processing are that they inevitably lead to purposeful changes in action and to changes in interaction with the environment [12]. However, the mathematical models necessary to describe these changes in human activities are not available yet in the known literature of the required quality. The situation can be changed by applying various approaches to describe changeable activity, such as the theory of functional systems [13], if it is described mathematically with appropriate formal means. My research is devoted to the construction and application of such a means. The work includes conceptual and formal models of information application for activities in systems; the formal models obtained were used to describe formal definitions of a set of urgent practical problems. As a result, it is now possible to solve practical problems, described as mathematical problems, using mathematical methods.

V. Elementary Information Application Models Examples

To further facilitate the development of information application models we suggest elementary information application models and than, based on them, models of systems of

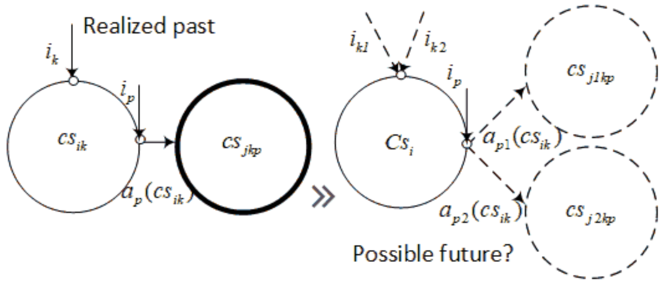

Fig. 5. Obtained Information i_k Application as the Reaction $a(cs_i)$, determined as deterministic function of information obtained from the environment

elementary models. Such systems of models may take form of sequences, networks, graphs of elementary models and their markings.

Each elementary model built as model of information application in the course of simplest (elementary) complex state transition.

We assume that complex states include information part and complex states transitions may depend on information received (and within complex state) or other information.

Such complex states dependencies takes for of cause-and-effect relationships and may be mediated by humans.

A. Information Application Models Examples

1) Information Application as the Reaction on Information Obtained from the Environment of the Object: In the Fig. 5: at the left of the Figure, the model of realized past complex states sequences is shown.

Given that the information obtained or received was realized (became the factual one), only one complex state can be realized in each moment of time, as a result of cause-and-effect relationships between states, and only one pair of complex states (one set of transition $a_p(cs_{ik})$ characteristics) can be realized.

In the case of elementary model considered, in the Fig. 5, final state functionally depends on previous state and characteristics of factual information i_k, i_p obtained. Such dependence can be naturally represented as deterministic automata $\mathfrak{A}^d(i^{en}, Cs^p)$ on the past states Cs^p or stochastic automata $\overline{\mathfrak{A}}^s(i^{en}, \overline{Cs}^f)$ on possible future states $\overline{Cs}^f$.

The first complex state cs_{ik} in the pair of realized states $a_p(cs_{ik})$), related with the functional dependency $f_p(cs_{ik})$ to the second complex state, cs_{jkp}. The pair, in turn, corresponds to the transition (action).

Complex state inludes information i_k, i_p characteristics, and the transition a_p between complex states can be expressed, as functions f_p, f_p^a of the initial state cs_{ik} and the information i_k, i_p characteristics. In the case of modelling future such functions shall be deemed as stochastic functions.

At the right of the Fig. 5, model of pairs of states of the possible future shown. In the Fig., Cs_i depicts set of possible complex states, realized due to i_k or i_p (it is assumed they can not be factual together). Appropriately, a_{p1} or a_{p2} can be realized and either cs_{j1kp} or cs_{j2kp} will result from action realization.

To depict various variations of future, depending on information application and actions modes, performed depending on such information, we suggested ports notation and functionality.

Ports are part of diagrams used to simplify views of possibilities (capabilities in case of humans functioning in nature) during system functioning, caused by variability, information use, and choices of possibilities during functioning.

Such possibilities are considered appearing due to reflections of various kinds, including information transfer or processing. Such reflections are kinds of reflective activities, which alter states of our diagrams. Thus, ports shall be attached with states altered and associated with information obtained.

Existence of port in the state or in transition means there is variability of cause and effects relationships realization, attributed to this state or transition.

Existence of information application shall be attributed to some port and cause changes in the variability of cause and effects relationships realization, attributed to appropriate state or transition.

We consider information applications, related with human's activity, when considering ports. Thus, ports, designated with incoming information signs shall be deemed to be ports for designating varieties of capabilites.

Correspondingly, ports, related to just nature variability are not considered as related to (human) information processing, and suggested being depicted (in a future illustration) as black ports. So white ports considered here, are ones, processing (human related) capabilities. Black ones will be presented in a future examples as processing varieties and possibilities (related to the nature).

In the example considered, ports corresponds to alternation places, where information obtained or processed due to software components, services, or routines, which performs delivered for use under human supervision to potentially alter $a_p(cs_ik)$ performed. Once information delivered $a_p(cs_ik)$ becomes completely determined as ($a_{p1}(cs_ik)$ or $a_{p2}(cs_ik)$).

For example, obtained information may cause alternation in process outcomes predictions and thus, instructions to perform further activities may be changed in such a way, once performed in changing environment they cause better outcome. Operations available for ports: drill in, drill up, drill through, drill to, drill across. Various ports can be connected with cause-and-effect, input-output and other kinds of relations and associated with states or with transitions.

Let us consider other possible kinds of elementary models, which differ from already discussed in that, from where information obtained, which is related to alternation.

2) Information Application as the Reaction on Information Obtained from the Object itself: In the example considered in Fig. 6, ports attached to initial state and transition from it, and associated with information obtained due to software components, or services, which considered as a part of the object or activity with it.

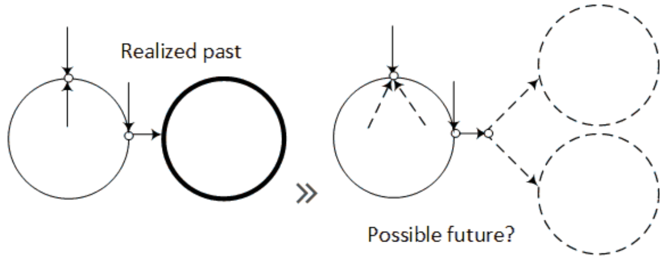

Fig. 6. Obtaining Information i_k from within object and application of the information obtained to activity $a(cs_i)$ as the reaction of this object activity (determined as the function of information obtained)

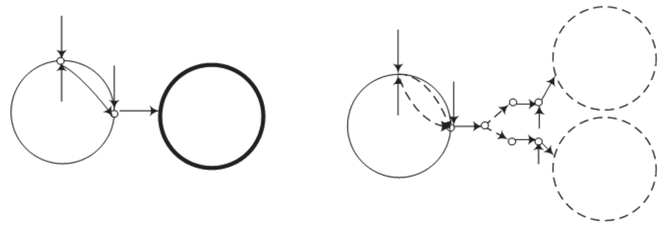

Fig. 7. Obtained Instructional Information Application as the Reaction, determined as deterministic function of information about activities

For example, obtained information can be information about details of object states just achieved. Instructions to perform further activities may be represented as a result of functions defined on information obtained. These functions usually defined before functioning in such a way, that changed actions in performance should cause better outcomes.

In the case depicted in Fig. 6, specified ports associated with information input (associated with the information arrow), and output (associated with complex state), information processor, predetermined instructional information for further activity.

3) Information Application as the Reaction on Instructional Information Processed inside the Object: In the example considered in the Fig. 7, ports information obtained from environment as well as from object is processed by software components, services, or routines inside the object to obtain new instructional information (unavailable at the moment of information arrival). It is suggested that such instructional information differ, depending on the information obtained.

For example, obtained information can be information about details of states, about possible modes of actions and their sequences, determined by current technology. Thus, instructions to perform further activities may be changed according to information obtained, in such a way, once performed in current changes of the environment, changed actions should cause the better outcome.

In the case depicted in Fig. 7, specified ports associated with information input (associated with information arrows), output, information processor, activity processor (information actuator for activity).

As a result of the sequence of ports fulfillment different complex states can be realized.

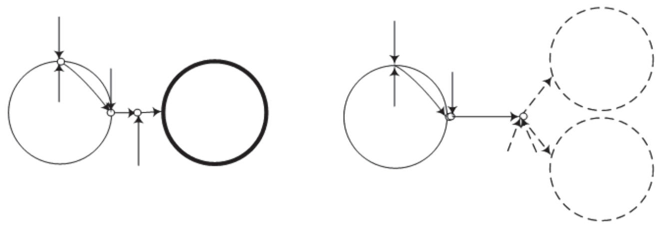

Fig. 8. Information, Obtained from the Environment about Activity – as the Reaction on chain of Information obtained

4) Information Application to Activities as the Reaction on Information about Activities, Obtained from the Environment: In the example considered in Fig. 8, chain of ports considered. The information in the figure is obtained as a result of software components, services, or routines applicatrion both inside and outside the object.

For example, obtained information can be instructional information changes, obtained from outside the object of consideration (interest). Thus, complex states and instructions, which will be applied to perform the further activities, may be changed according to the chain of information obtained.

In the case depicted in Fig. 8, specified chains of ports are associated with various information inputs (information arrows), information processor, activity processor (information actuator for activity).

Chains of ports with particular information applied can be transformed into the models in the form of trees of states, where chains are associated with alternative branches of the tree. Probabilistic branching is possible to depict chains of future states probabilistic measures.

Such measures as well as measures of activities effects correspondence to the changing demands can be used to built measurable spaces of functioning outcomes under various information conditions. These spaces are suggested as algebraic models of information application outcomes depending on various information conditions. We suggest using these spaces to solve various problems related to pragmatics of information application [14].

Each tree mentioned and, potentially, used to build measurable spaces of information application spaces, represents results of ports-information model parsing, in such a way, that tree corresponds to all possible realizations of information use and ports-information graphs depict how such realizations formed.

Graphs, shown on the right sides of Fig. 5 – 8 can be considered, as such trees examples, while graphs on the left sides – as ports-information graphs examples. Graphs on the right side are suggested to be used for measures computation and graphs on the left — for the structuring of measure spaces. To build tree models of the right side, parsing of the left side with use of automata on ports sequences with information can be used.

Above-mentioned examples of models served us further as the basis to create complex models of information chains application, based on complex states, ports, and associated with ports capabilities alternation with information. Some examples of such models are illustrated below.

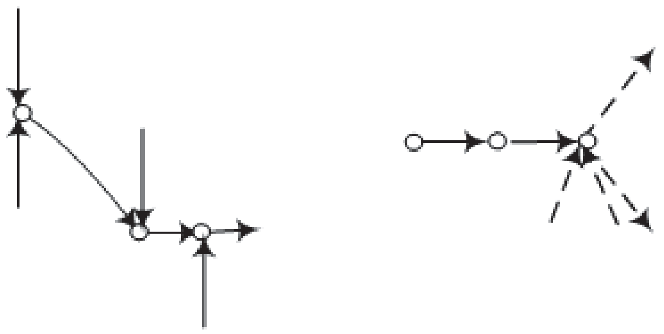

Fig. 9. Composite Model of Information Application to Change Capabilities Associated with Ports

B. Composite models of Information Chains Application, based on formalisms suggested

Introduced functionality of ports, depicting changed capabilities and their dependence on information obtained or received allowed us to create models of changed capabilities / information sequences as well as other models, which depicts interrelated information and capabilities flows. Let us discuss such models examples.

1) Composite models of Information and Capabilities Chains Changes: In the example considered in the Fig. 9, chain of ports and altering them information considered.

Each port associated with capabilities changes – factual (in the present) or possible (in the future). Appropriate branching can be represented as a bipartite graph over sets of capabilities. Capabilities associated with ports, and two kinds of relations used: ones representing cause-and-effect relationships (associated with part of the arrows) and ones representing information flow relationships (associated with another part of arrows). The model alike is a kind of (Bipartite) graph over sets model. Appropriate theoretical instrument for such formalism suggested by authors, is category theoretic model. As well, it can be represented by automata on category of sets [15], [16].

2) Multidimensional models of Information and Capabilities Chains, based on formalisms suggested: In the example considered in Fig. 10, chain of ports and altering them information separated to two planes. One plane associated with information flow relationships and another plain - with cause-and-effect relationships between ports and appropriate capabilities. Such representation may allow to represent each part of bipartite graph on its own plane.

Operations of drilling in and drilling out by such relations can be associated as a result, with each plane.

VI. Conclusions

Concept and functional models of information application for system functioning were elaborated in the paper on the example of DevOps planning. Conceptual and formal models presented can be further used to formulate a set of typical

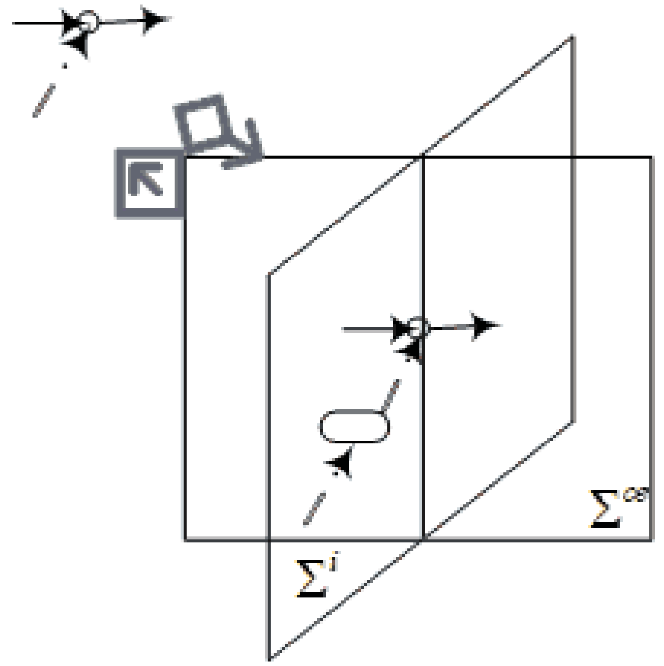

Fig. 10. Multidimensional model of Information Application for Capabilities changes with ports formalisms use

problems of information application for system functioning. Models and formal definitions of problems discussed are expected to pave the way for future research, potentially leading to the creation of a contemporary theory of information application for activity, 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. We suggested representing models of information application with concepts of complex state, ports, and their transitions under information flows conditions. Examples of such models are shown for DevOps case. It is shown, that models of this kind can be represented as bipartite graphs over sets and as automata on appropriate categories of the sets of capabilities. Some examples of such models suggested.

The future scope includes the further development of formalisms suggested. These formalisms, once established, could be integrated into system and complexity science, cybernetics, and various activity theories to construct models of information application and techniques for predicting results of information application. Consequently, researchers will be empowered to solve a diverse range of problems, which are associated with improving information application and deliberately modifying systems and their operations in response to changing conditions and changing information technologies use.

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