Toward the Theory of Using Information for Actions in Systems: Prospects for Research and Reviews

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Abstract—**This article considers current research prospects, theories and mathematical formalism related to the value of outcomes of digitalisation, their informational value for actions and using information for various types of activities in an array of systems (e.g. production, business, economic, social and organisational systems). Following a review of literature on digitalisation, digitalisation in organisations and the digital economy and society, theories and mathematical techniques for modelling the use of information in various kinds of systems activity were identified, as were blind spots and gaps in research on information used in system actions. In particular, a multidisciplinary gap exists between the need to solve problems in using information for further actions in various systems (i.e. mathematical and theoretical systems-related problems) and available theoretical and mathematical means to solve such problems. Difficult to overcome given its multidisciplinary nature, that gap appears on the border of systems theory, human action theory, economic theory, organisation studies, cybernetics, psychology, theory of mind and mathematics. In response, this article also considers the role of information actions in system action and proposes a mathematical theory on using information in such actions.**

I. INTRODUCTION

Despite the ubiquity of the buzzwords “digital transformation” [1]–[7], “digital economy” [8], [9], “digital production” [10], [11], “digital platforms” [12], “digital education” [13] and other digital phenomena [14], their exact meaning remains unclear in conceptual and formal models, frameworks and theories used to measure and predict results of the phenomena and design those models, frameworks and theories. Added to that, such phenomena, their appearance, use and value remain conceptually unclear, especially when those phenomena are emerging. Researchers have thus discussed the need for digital philosophy [15], [16] that considers the informational character of phenomena in the physical world in order to explain the role of information and information actions in both human activity and nature [17], [18] from different perspectives.

II. METHOD OF REVIEWING LITERATURE ON DIGITAL PHENOMENA

A systematic literature review [19] of current concepts in research on digital phenomena and the formal methods, theories and trends that they support was conducted to answer three research questions (RQ): RQ1: What are the major blind spots and gaps in research on digital phenomena, and why do they exist? RQ2: What are possible prospects and means for research to overcome the identified blind spots and gaps? RQ3: Which theories are best suited to overcome those blind spots and gaps? The algorithm used to conduct the literature review consisted of a few recursive steps. First, first-layer searches were performed for keywords already appearing in the core collections of Scopus and Web of Science (WoS): “digital transformation”, “digital economy”, “digitalisation” and “digital business”. Many searches were made to cover a broad set of specific keywords and corresponding research prospects in publications appearing in research journals indexed in the core collections of WoS and Scopus for at least the last 5 years. The tens of thousands of results yielded by first-layer searches were processed statistically in R and R’s bibliometrix package. Results were used to further investigate the relationships between the identified keywords (Fig. 1), and their co-occurrence and to pinpoint publications with answers to the RQs. As a result of the systematic searches and a review of the most-cited sources, a cloud of keywords appearing in the publications was developed (Fig. 2).

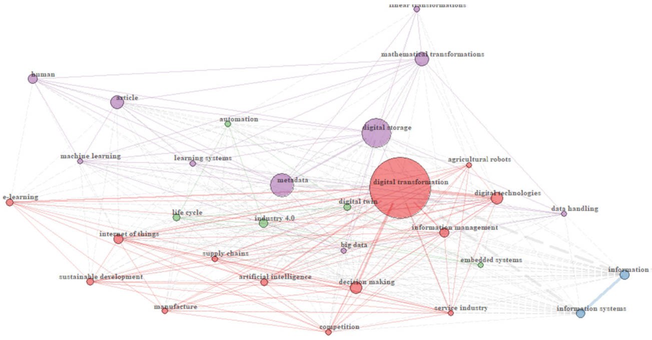

Fig. 1. Graph of the co-occurrence of keywords generated by bibliometrix

Second, the highest-ranked articles and reviews were identified. All such reviews and articles were published in the highest-ranked journals in the core collection of WoS, preferably marked as “Highly cited” and “Hot papers”. Especially from critical articles and review articles, more keywords were extracted to further pinpoint articles with answers to the RQs. As a result, the searches revealed major research articles addressing concepts, theories, theoretical frameworks, mathematical models and methods related to using information for actions in systems. After that, the selected articles were studied to answer RQ1–RQ3, steps above were repeated for the new keywords discovered, and answers to the RQs were refined.

III. RESULTS OF THE LITERATURE REVIEW

This section refers to the articles reviewed as a result of recursive searches with the following major keywords:

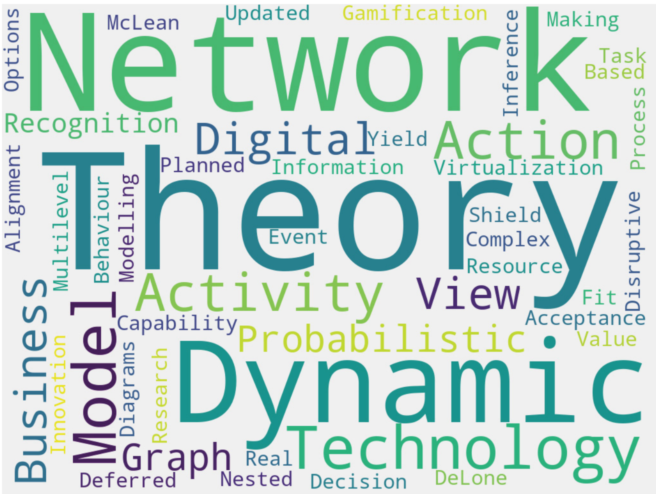

Fig. 2. Cloud of keywords appearing in the publications

“digital capability” [20]–[24], “digital platform” [25], “digital entrepreneurship” [26]–[28], “emerging systems” [29], [30], “business value of IT” [31]–[34], “digitalisation capability” [7], [20], [35], [36], “organisational capability” [37], [38], “circular economy” [39], “digital capabilities” [20]–[22], [35], [36], [40], “dynamic capabilities” [41]–[45],“sharing economy” [8], [46]–[52], “action theory” [53]–[56], “network science” [53], [57], [58], “language-action approach” [59]–[61], “dark side of IT” [62], [63], “real options” [64], [65], “constructor theory of information” [17], [18], “sustainable economy” [45], [66], “emerging systems” [29], [30], [67], “system of systems” [68], [69], “digital culture” [70], [71], “action research” [72]–[74], “Industry 4.0” [10], [75]–[77], “blockchain technologies” [78]–[81], “AI digitalisation” [82], ”Labour digitalization” [83], [84] , ”Big Data Analysis” [85]–[87]. In order, the nine most popular journals in which the reviewed articles were published were the International Journal of Information Management, Management Information Systems Quarterly, the Journal of the Association of Information Systems, Information Systems Journal, Information Systems Research, the Journal of Information Technology, the Journal of Management Information Systems, the Journal of Strategic Information Systems and the European Journal of Information Systems.

IV. Answers to the RQs

Although numerous blind spots and gaps exist in knowledge about digital phenomena, the major ones are listed in the following answers (A) to the RQs:

A.1.1. There is no consensual conceptual understanding of digital phenomena and their differences with, for example, information-related phenomena. Most authors, however, agree that the term “digital” is more applicable than “informational” due to the far larger scale and ubiquity of digital technologies.

A.1.2. Technologies traditionally listed among digital technologies are big data, artificial intelligence, the Internet of Things and digital ledger technologies, although the list continually changes. Because the criteria for including technology on the list remain unclear, however, designing new technology from scratch for inclusion on the list is problematic.

A.1.3. Despite a general understanding and conceptual descriptions of various outcomes of digital phenomena, both good and bad, and risks related to using digital technologies, formal common models for understanding the mechanisms of digital phenomena and their outcomes are lacking. Such mechanisms of using information, for example, are described as possible digital business processes, while the results of digital phenomena are described as the results of the digitalisation of business models. Nevertheless, theory on the use of digital technologies and its consequences based on mathematical models and methods has not yet been developed.

A.1.4. Sufficiently common formal models of mechanisms of using digital phenomena are absent, largely due to the exceptionally multidisciplinary nature of research on such phenomena, which encompasses the human mind, intelligence, action studies, systems science, cybernetics, computer science and complexity science, to name a few. The results of digital phenomena cannot be explained based exclusively on, for example, computer science but should be understood as the results of using information for various kinds of actions in several types of systems and their environments. Based on mathematical models and methods, a theory of such activity has not yet been developed, nor has one about using information for system action based on mathematical models and methods. Although such circumstances complicate the creation of proper mathematical theory on the use of digital phenomena, various theoretical means exist to explain particular mechanisms of such use and its outcomes.

A.1.5. No sufficiently general theory exists to explain digital phenomena or the use of information, which has resulted in a gap between, on the one hand, the need to formalise and predict results of possible new digital phenomena, evaluate results of using information, design future new digital phenomena for better results based on formal methods and, on the other, available concepts and the formal frameworks, mathematical models and methods suitable for such formalisation, prediction and design that those concepts support.

V. Review of Similar Areas of Research

As a result of the review conducted, insights into theories, conceptual and formal frameworks, models and methods (i.e. theoretical means) in research areas (RA) similar or analogous to the theory to be developed on using the information in system actions and that can contribute significantly to the field were obtained and are presented in what follows.

RA.3.1. Although many theoretical means explain various facets of digital phenomena, none can yet be used to model and predict the future use of the results of digital phenomena and thus to design, synthesise and engineer such phenomena using predictive or prescriptive mathematical models and methods.

RA.3.2. Among those theoretical means, the most promising for modelling or predicting the future use of the results of digital phenomena are action theory [53]–[56], [88]–[91], complexity theory [92], [93], deferred action theory [94], [95], system potential theory [96]–[101], complex and dynamic networks theories [102]–[105], network science and probabilistic / fuzzy dynamic graphs theories [106]–[108], dynamic decision making [109]–[111]. Considering those theories, the hypothesis developed for the research presented here was that creating a unified conceptual model of digital phenomena based on action theory, deferred action theory and system potential theory and utilising mathematical models and methods of those theories can enable the creation of new mathematical models and methods to overcome at least one mentioned gap (A.1.5). To confirm that hypothesis, new models for using information operations for system action should be built that are based on the results obtained—that is, models of families of alternative stochastic action networks ($FASAN$). On the one hand, some such models are already in use to create the necessary mathematical dependency for models of information operations and system actions. On the other, new models should be based on the theoretical results obtained by applying the theories mentioned above.

RA.3.3. Other theories that can be used and should be further examined to build the needed mathematical models and methods about using information for system action are:

(3.3.1) Updated DeLone and McLean model [112]–[114].

(3.3.2) The technology acceptance model [115]–[118].

(3.3.3) Task-technology fit theory [119], [120].

(3.3.4) Process virtualization theory [121]–[123].

(3.3.5) Theory of the deferred action [95].

(3.3.6) Resource-based view theory [124]–[126].

(3.3.7) Dynamic capability theory [42], [127]–[130].

(3.3.8) Business value of IT [131]–[134].

(3.3.9) Public value of IT [134].

(3.3.10) Business model innovation [135]–[137].

(3.3.11) The technology–organization–environment framework [138].

(3.3.12) Multilevel complex network science [7], [32], [58], [79], [92], [108], [121], [139]–[152].

(3.3.12) Circular economy [39], [135], [137], [153], [154].

(3.3.13) Strategic alignment of digital technologies and strategic goals [45], [126].

(3.3.14) Action event recognition [155].

(3.3.15) Complex project networks [90], [156]–[167].

(3.3.16) Yield shift theory [168], [169],

(3.3.17) Theory of planned behaviour [170]–[172].

(3.3.18) Digital innovation management [28], [85], [86], [173], [174].

RA.3.4. The suggested theories for developing the use of information in system actions are good candidates for theoretical bases for digital systems engineering [175] and, by extension, practical engineering.

VI. MAJOR PROSPECTS FOR RESEARCH

RA. To overcome the identified gap (A.1.5), I propose the following major prospects for research.

RA.1. Explaining the role of the use of digital phenomena use in human action, its results and the characteristics of such results depending on the characteristics of the phenomena themselves by using mathematical models should make it possible to explain the results of various current and projected digital phenomena, whether in culture, social life, economics and business, to name a few types of human action. The distinguishing feature of the proposed expansion of action theory should be based on the fact that such theory already explains the roles of information, information processing and knowledge as prerequisites for human actions performed in society, albeit only conceptually. The mathematical model of dependence between characteristics of information actions (i.e. as independent variables), the quality of material actions (i.e. as a dependent variable) and environmental and system characteristics (i.e. as parameters) should be created with theory to be developed. Although mathematical models of such dependencies were not found in the literature reviewed, the required models could be built based on models already created to estimate system potential. In their current form, models to estimate system potential allow probabilistic dependencies between possible sequences of characteristics of system and environmental states, characteristics of managerial information operations on the border of the system and its environment and characteristics of networks of actions (i.e. operations). In turn, the results of such networks of action, depending on the characteristics of the state and managerial operations, can be evaluated as characteristics of the quality (i.e. dependent variable) of the network of actions depending on independent variables (i.e. characteristics of system and information actions). Each information action can yield different networks of actions fulfilled depending on those actions' characteristics, the states of the system and the dynamic and/or probabilistic states of its environment. Such mathematical formalism is represented by dynamic stochastic graphs and/or theoretical models known as $FASAN$ models, the use of which is thoroughly described in what follows as a particular example of models that can be created for theory on using information for system action.

RA.2. Once the use of digital phenomena for actions' results is explained, as described above, and mathematical models created, researchers can use such explanations for the predictive mathematical modelling of the use of digital phenomena, for predicting the results of actions and for prescriptive mathematical methods for the design of future digital phenomena (i.e. synthesis). To create such models, a new set of models should first be created, ideally as extensions of $FASAN$ or similar models. In their current usage, $FASAN$ models are valuable for processes, described as alternative sequences of stochastic projects interrupted by managerial information operations and corresponding information operations used to interrupt and alter sequences of projects depending on changes in the system's environment. Of course, such operations are only a fraction of possible kinds of information operations and represent only a minor part of possible changes in subsequent actions that information operations may induce. Future research thus has yet to describe the lion's share of possible kinds of information operations. Answers to the RQs allowed formulating major prospects (P) for developing the theory of using information for system actions, hereafter referred to simply as "theory:"

P1. The theory should allow linking information actions characteristics with further actions intended for material and energy transformation (material actions), characteristics of the quality of their results. For this reason, causal relations between different types of actions – information actions, their cause, their characteristics, further system actions, their results, and their characteristics – should be modelled first conceptually and then formally. As of now, such models not found in literature observed, except very particular case described by $FASAN$ models and managerial information actions to interrupt and alter project networks.

P2. The theory should allow the evaluation of possible sequences of states and actions of different types depending on the characteristics of information actions.

P3. A set of possible sequences of states related to causal relationships due to possible sequences of actions of different kinds should be modelled. Those sequences should be measured according to the results caused by sequences of activities and their correspondence to demands, which are dynamic and provided by the system's environment.

P4. Measures of how sequences of actions correspond to dynamic demands and sequences of characteristics of states and actions, including possibilities of realizing such sequences depending on information actions and environment-based actions, should be used to evaluate dependent variables (e.g. the potential of the system's indicators). Such dependent variables should be computed based on functions of independent variables, ideally characteristics of actions, and should be used to solve practical problems of the theory.

P5. The theory should contain a conceptual framework to formalise the practical problems described above as mathematical problems of optimal choice, mathematical programming or game theory using formal means. According to the literature reviewed, no widespread modelling techniques allow linking characteristics of information actions with subsequent actions intended for material and energy transformation (i.e. material actions) and characteristics of the quality of their results. Such techniques can be created, however, as the use of $FASAN$ models suggests.

VII. INFORMATION ACTIONS AND THEIR ROLE IN SYSTEM ACTIONS

Information actions are needed [176] to provide a system's required interaction with its environment under changing conditions and the required quality of system actions and their results in that environment [110]. Indicators of a system's capability are used to estimate indicators of such quality and dynamic capability, organisational capabilities, system dependability and IT performance. Furthermore, indicators of those types can be used to solve various practical problems as mathematical problems of estimating indicators and a system's elements, capabilities, characteristics of information operations and their synthesis based on indicators. Such indicators are dependent variables in the mathematical problems considered and are estimated to be a function of possible characteristics of the system and its actions. To estimate such properties, a complex of models is necessary [107], one that should reflect the interactive system, its different kinds of environments and its information operations. Information actions (i.e. operations) are additionally required to check the system and its environment's functioning states, to measure the correspondence of the current and projected states to the requirements, to prescribe changes in actions to be performed by the system and to alternate the system's functioning. Changing the environment may cause the system to change its goal due to its interaction with the environment and to fulfil other information actions (e.g. learning actions). The use of information actions reacts to changes and, as a result, provides required interaction with the environment, as can be examined based on the operational properties of such use, which characterise the results of the activity with objects and the correspondence of the activity to (changing) demands. Operational properties are measured based on the effects (i.e. demanded results) of actions at the system's boundary and by those effects' compliance with the environment's requirements [109], [177]. However, because information actions and the characteristics of such effects' dependencies have not been studied in sufficient detail, the business value of the use of current (digital) IT is often problematic to measure.

Information actions are needed to provide required system interaction with its environment under changed conditions and needed quality of the system actions and their results in changing environment [178]. The system capability indicators are used to estimate such quality [3], [179] and dynamic capability indicators, organizational capabilities indicators, system dependability indicators, and information technologies performance indicators. Further, indicators of this property are used to solve various practical problems [180] as appropriate mathematical problems of indicators estimation and the system elements, capabilities, information operations characteristics synthesis based on indicators [181]. Such indicators are dependent variables in mathematical problems considered, and they are estimated as a function of possible characteristics of the system and its actions.

VIII. CLASSIFICATION OF INFORMATION ACTIONS AND PRINCIPLES OF MEASURING RESULTS

The first-level classification of information actions (i.e. operations) is illustrated in Fig. 3.

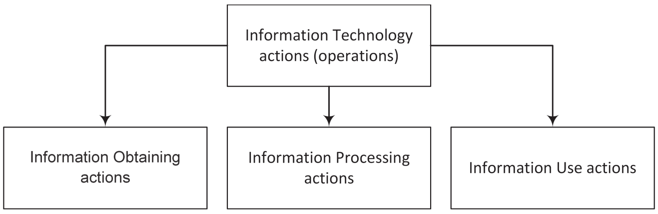

Fig. 3. First-level classification of information actions

The example of managerial information operation modelling, which contains three types of information actions, is considered in $FASAN$ models, represented as simple rules in tabular form. The goal of the first two kinds of IT operations is information itself. Therein, information Im means the existence of ideas or thoughts in the material world (i.e. outside the mind) in a form that functions as a record of an information carrier. We distinguish information from its (general) reflection [17] form, which can be found in material interactions without any human action involved. Thus, we consider information to be a particular kind of reflection used in human activity. For the difference of actions to obtain information a^o:$M, m \rightarrow Im$ is their input Mm can be of the material world or mind, but information-processing actions a^{Ip}:$Im_1 \rightarrow Im_2$ take information Im_1 as input and produce informationIm_2 as output. That information can be prescriptive Imp or descriptive Imd or the system. Last, the use of information actions a^{Iu}:$Im \rightarrow Mm$ take information Im as input and produce changes outside (M) or inside (m) mind. Such changes are made by humans or devices (actuators and robots) using information Imp if information is used outside the mind and Imd or Imp if inside. Changes occur because information Im may alter the way in which humans and/or devices interact with the material world (M) or mind (m). Thus, changes in Im may induce changes in Mm. Such change is the effect of using Im and of using IT, the latter of which describes operations a^j of different kinds j and their relationships with other operations, with minds and with the material world. Thus, IT describes possible IT operations and chains of information operations. In that light, the first-level classification provides a high-level explanation of how IT is used and the effect of information. With that high-level description, we can formulate principles for measuring and managing the use of information.

Principle 1. Effects of the use of information are changes inside or outside the mind. We should measure the results of such use according to characteristics of the change, their relationships with change and the extent to which changes comply with human demands. In the rest of this paper, we will restrict our discussion to effects outside minds because the objects under study are technical, organisational and socio-organisational systems. We will restrict to effects outside minds in further material because objects under study are technical, organizational, and socio-organizational systems.

Principle 2. We can measure quality of information use in a given system according to the characteristics of changes caused by information Im, which changes the relationship between action elements and action effects and their compliance with human demands. For such effects, the measure $\delta \left(Im,\ \mathrm{S}\right)$ of the quality of information use (i.e. application) may have the form $\delta \left(Im,\ \mathrm{S}\right) = \Psi \left(\mathrm{Im}, \mathrm{S}\right) - \Psi \left(\mathrm{S}\right)$, in which $\Psi \left(\mathrm{Im}, \mathrm{S}\right) -$ is the measure of the system's capability as system potential measure under assumption information Im obtained with the It It used to alter the system's S functioning, whereas $\Psi \left(\mathrm{S}\right)$ is a measure of the system's potential under the assumption that Im was unavailable (e.g. not obtained, not created or not constructed) due to other IT being used. Information-obtaining actions are classified in Fig. 4.

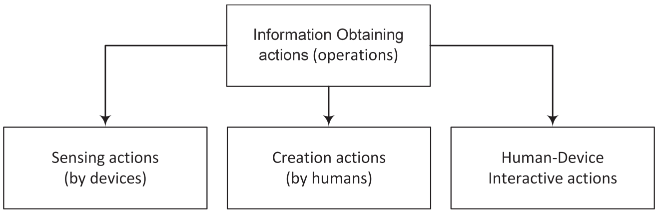

Fig. 4. Second-level classification of the retrieval of information actions

Let information-obtaining actions (i.e. operations) be a^o=$\{\ a^s, a^c, a^{hd}\ \}$, in which a^s- is sensing actions (i.e. output information provided by devices based on the material world), a^c is creation actions (i.e. output information created by humans) and a^{hd} is human-device interactions.

Next, let $Im_j = f_j \left(a^j\right)$, in which a^j- is the system of information actions and Im_j is the output information of a^j, provided by $f_j \left(a^j\right)$. Thus, $\Delta \left(a^j, \mathrm{S}\right) = \Psi \left(f_j \left(a^j\right), \mathrm{S}\right) - \Psi \left(\mathrm{S}\right)$ as the measure of the quality of information operations a^j, measured considering all possible actions a^{j*} that result from a^j until effects in the material world manifest. After those effects manifest, the new chain of information actions possible begins with obtaining information actions. As a result, sequences $< a_1{}^{j*}, \ldots, a_i^{j*}, \ldots a_n^{j*} >$ possible, in which $a_i{}^{j*}$ is sub-sequences of possible information operations that lead to possible changes in the material world. In general, those sequences may include sequences of information actions that cause changes in human minds. Last, we use inevitable changes in actions in the material world as markers of each contour of the fulfilment of information actions, which yields a third principle.

Principle 3. The contour of possible changes due to information actions ends when changes in the material world occur. At that point, we can measure the results of using information. The possible contour of possible changes should be measured according to changes in practice (i.e. in the material world). Because possible sequences of such contours should also be considered, possible sequences of realising contours should be measured. Thus, once results are obtained due to the next part of the contour, subsequent possible contours of purposeful changes with further information actions should be considered and measured in their sequences. Information-processing operations are classified in Fig. 5. Information processing actions a^p=$\{\ a^{ts}, a^t, a^c\ \}$, in which a^{ts} is time displacement and actions of moving through space, a^t is the form transformation actions and a^c is the creation of new information based on current information. Let a^{jp}=$a^p \left(a^j\right), a^j$, f_{jp}=$f_p \left(a^p\right) \circ f_j \left(a^j\right)$ such that $\Delta \left(a^{jp}, \mathrm{S}\right)$ is the measure of the quality of the information operations a^p. a^j quality is measured considering all possible actions a^{jp*} that results from a^{jp} until effects in the material world manifest, after which the next possible contours of purposeful changes with further information actions should be considered. Operations of using information are classified in Fig.6.

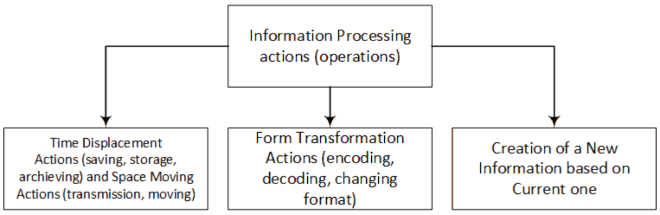

Fig. 5. Second-level classification of operations of information processing

Information use actions a^u=$\{\ a^a, a^{hd}, a^m\ \}$, in which a^d is the change in the actions of the material world as the actualisation of information by devices (i.e. actuators), a^{hd} is the change in the actions of the material world as the actualisation of information by human labour and equipment and a^m is the creation of new information based on current information. Let $a^{jpu} = a^u \left(a^p\right), a^p \left(a^j\right), a^j$, such that $f_{jpu} = f_u \left(a^u\right) \circ f_p \left(a^p\right) \circ f_j \left(a^j\right)$. Next, $\Delta \left(a^{jpu}, \mathrm{S}\right)$ measures the

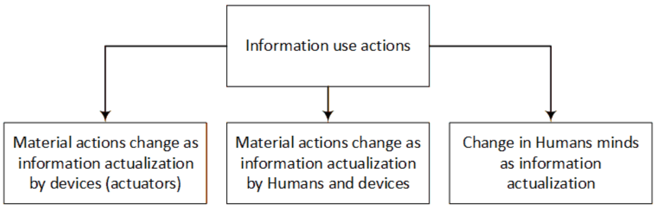

Fig. 6. Second-level classification of uses of information action

quality of information operations a^u considering all possible actions a^{jpu*} that result from a^u and taking into account subsequent contours of purposeful changes with the use of further information actions. Each contour of the quality of purposeful changes is estimated by its final $\Delta\left(a^{jpu},\mathrm{S}\right)$ and the probability $\mathrm{P}(a^{jpu},\mathrm{S})$ of the contour's realization. The quality of each of the mentioned information actions can be estimated as results of possible corresponding a^{jpu},S after those actions. To estimate each chain C_n of a contour's corresponding measure, $\omega\left(C_n\right)$ was constructed. For example, each contour can be measured as:

$$\omega\left(C_n, S\right) = <P\left(C_n\right), \Delta\left(a^{jpu}, \mathrm{S}\right), n \in N >, \tag{1}$$

in which $P(C_n) = P({a_n}^{j*}, S)$ ...$P({a_n}^{jpu}, S)$, ${a_n}^{jpu}$ is the final system of contour C_n of actions' changes in the material world and $P({a_n}^{j*}, S)$ is the- first set of information actions in the contour of purposeful changes. For all possible $n \in N$ the multidimensional measure $\Omega\left(S, It\right)$ was constructed, in which $It-$ is IT used for the the system's S change in functioning. Measuring $\Omega\left(S, It\right)$ characteristics (e.g. quantiles, moments and mixtures of characteristics) may serve as a system's potential vector $\Psi\left(S, It\right)$ or scalar $\psi\left(S, It\right)$ indicator. For example, if the mean of $\Omega\left(S, It\right)$ is used:

$$\psi\left(S, It\right) = \sum_{n=1}^{N} P\left(C_n\right) \cdot \Delta\left(a^{jpu}, \mathrm{S}\right). \tag{2}$$

then measures (1,2) can be used to estimate indicators of other properties, which characterise various aspects of the quality of the system change regarding IT use. To estimate indicators of IT performance or digitalisation's effects under conditions of change and interaction, we propose [182] [100] [178] using the difference between the values of the system's capability indicators for the use of new (e.g. digital) IT and primary (e.g. traditional) IT. Thus, new IT It_a indicator $\Phi(It_a, It_0)$ compared with primary IT It_0 can be estimated as a difference:

$$\begin{aligned} &\Phi_1(It_a, It_0) := \psi_1(It_a) - \psi_1(It_0), \\ \text{or, } &\Phi_2(It_a, It_0) := \psi_2(It_a) - \psi_2(It_0). \end{aligned} \tag{3}$$

in which $\psi_i(I_j)$ is the scalar indicator i of the system's capability under condition IT j used.

IX. COMPLEX DYNAMIC ACTION NETWORKS FOR MODELLING THE RESULTS OF INFORMATION ACTIONS

To model the results of information actions and measure IT's value according to the suggested principles, researchers have to compute $\Omega\left(S, It\right)$ multidimensional measures. One of the possible ways to compute such a measure is by using models of alternative stochastic projects performed by the organisational system in volatile environments. Because the information operations cause the alternations of the stochastic projects, computing the measure of correspondence should consider all possible sequences of stochastic projects depending on the results of environmental impacts and managerial information operations. Such alternative stochastic projects can be modelled as dynamic complex networks [105], alternated due to volatile impacts of the environment. We have suggested the dynamic complex network variant $FASAN-$ [160]to compute multidimensional measure $\Omega\left(S, It\right)$, which allows the modelling of probabilistic projects with alternations, performed by a unique information action, to interrupt the current project and launch alternative projects instead. Unlike $GERT$ [183] and alternative stochastic networks [184], the $FASAN-$ based project is alternated as a whole. States of alternation are probabilistic and may include conditions of the environment.

$FASAN$ models are defined based on sets of graphs (i.e. the base of $FASAN$), relationships between them, sets of states and mappings between graphs and states such that families (i.e. related sequences) of alternated action networks, relations and mappings between networks and states (i.e. cuts of networks) can also be defined. In turn, mappings of states of the system and its environment to the new network in the family of networks can be defined as well. As a result, complex networks (i.e. trees of possible action networks) and their alternations are formed. Precisely, in $FASAN$ the base is hyper-graph edges (i.e. sets) that describe complex states and relationships between them and the realisation of probabilistic stochastic action networks under given conditions of environment and the system's chain of states. Networks represent sets of actions and relationship between them, which cause state transitions.

With the use of $FASAN$, it is possible to describe alternations of the system functioning [184], including alternations defined by networks of operations. The network's alternation case maps the network actions to the complex states, modelled as a hyper-graph of states, of each possible alternation. Each possible alternation state corresponds to one of the network cuts. We developed algorithms to map alternative networks of possible cuts and, in turn, alternative states. Pairs of possible alternative states of the system and its environment are thus mapped to the complex state of the new (i.e. alternate to previous) network's beginning. That (alternated) network can be mapped again to the set of complex states of possible alternations. Next, algorithms of the network cut formation and their use for alternations allow forming trees of complex states and networks depending on possible alternative scenarios.

Let us designate $H = (E, N)-$ as a hyper-graph with hyper-edges $e_s \in E$, such that each edge e_s associated with workplace Wp_p and its state . Each action a_i in the network N_p is associated with two states: start state S_n^s and finish S_m^f states. Each state S_s corresponds to the result of only one action or inaction. Thus, by knowing lists of actions $c_k(T_m)$ (i.e. cuts) that are performed at given moment of time T_m, we can compute system states $S^s(c_k, T_m) = \cup_{c_k} S_s, s \in c_k$.

$FASAN$ is set of actions $A = \{a_i\}, a_i \backslash S_s(Wp_p, e_s)$, set of networks $N_p \subseteq (A_p \in A, E_p \in A_p \times A_p)$ and set of mappings in three types:

$f^{NS} : N_p \rightarrow \{S^s(c_k, T_m)\}$ is the- type of mapping from network to possible states $S^s(c_k, T_m)$ of the system;

$f^{SS} : (S^s(c_k, T_m), S^e(T_m)) \rightarrow \{S^a(T_m)\}$ is the type of mapping from the pair of the system S^s and environment S^e states to the possible states S^a of alternation of the system functioning;

$f^{SN} : S^a(T_m) \rightarrow \{N^q\}$ is the type of mapping from the alternation $S^a(T_m)$ state to the possible alternative network N^q of operations;

We have used networks of operations with start, finish and delay vertices. The network of operations N_p is the directed acyclic graph, such that each vertex is associated with an action (i.e. operation) on certain individual workplaces Wp_p of the system or with inaction (i.e. delay or waiting or start or finish the operation). The start vertex relates to the operation of a ready-and-waiting state to start at the required moment; it has no incoming edges. By contrast, the finish operation is the operation of waiting to report the results of the action network. We plan to use the theoretical formalism of $FASAN$ with process-mining techniques to expand process mining and process science technology [185] with stochastic time alternative networks of operations. Part of the $FASAN$ branch with the two alternations, two states, four mappings and two alternate networks is shown in Fig. 7. A^m designates "material" operations, A^i is information operations, D^m is the delay operations before material operation, D^i is the delay before information operation, and s designates complex states on the system's border and environment, modelled separately. One of the possible cuttings shown corresponds to one of the possible alternations resulting from the network of actions and the complex system state mapping of f^{NS} type, m_j^{ns} from the network to the complex state of the system and its environment, obtained with using information operations and resulting from the complex state of the system and its environment, shown as a triangle in Fig. 7. Next,the mapping of f^{SN} type, m_u^{sn} from the system and its environment's complex state s_j^{se} to the new (i.e. alternated) network $N_u(s_j^{se})$ can be realised. That mapping is provided with information operations as well. The results of the (second) information operation are prescriptions and descriptions needed to fulfil a new, alternated network; such prescriptions and descriptions form the state of the new (alternated) network start. The quality of the prescriptions and descriptions are determined by future corresponding measures of network family chains fulfilment at different moments of the system's functioning under varied conditions of the environment.

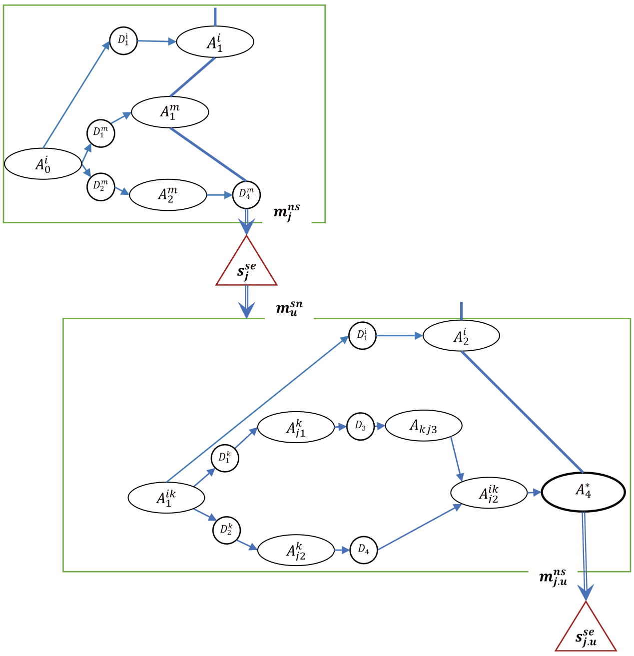

Fig. 7. The $FASAN$ branch fragment with two networks and two complex states

A computed multidimensional measure $\Omega\left(S, It\right)$ in Geo-View,, in which effects correspond to the requirements measure shown by (X), sequences of possible network actualisation by (Z), and total complex correspondence measure by (Y) surface extrapolation (by kriging method) for contours of information operations with a length of 1, is shown in Fig.8.

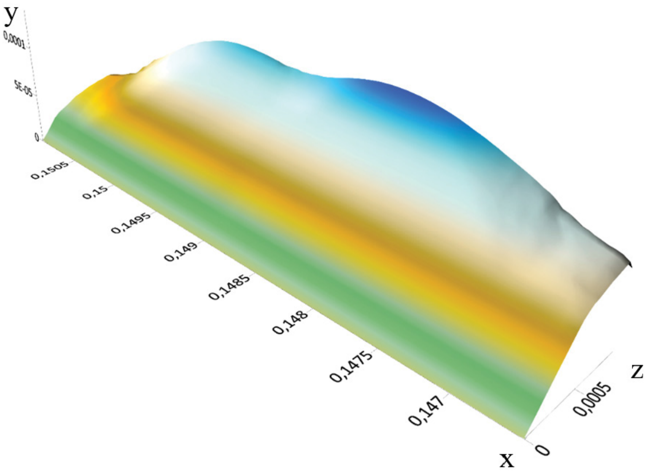

Fig. 8. Geo-View Surface Extrapolation (by kriging method) for contours with a length of 1

X. CONCLUSION

Research prospects, theories and types of mathematical formalism related to digitalisation results value, information used for various types of activities in a wide range of systems have been reviewed. The role of information and information activities in preparation, performing and changing future actions in various kinds of systems have been analysed as well. As shown, information is needed to predict and change the predicted future, and it is oriented towards future activities to change the future states of the system and its environment. Blind spots and gaps in research on using the information for further actions have been described, and, as a result, a multidisciplinary gap was found between the need to solve practical problems of using information for the action of various systems as systems theory and mathematical problems, on the one hand, and available systems theory and mathematical means to solve such problems on the other. At the core of that gap is the modelling of using information and using information actions in preparation, performing and changing future actions in various systems. The use of information aims to change the predicted future and is oriented towards future actions. The mathematical model of such information use is neither a model of the information nor a system model but a model of interrelated current and possible future (i.e. information and material) actions of the system and its environment which cause the possible future outcomes. Such a theory could be highly multidisciplinary and involve considerations of the human mind, information and intelligence, as well as psychological, systemic, organisational, economic and social aspects of the desired future actions, all depending on the characteristics of the information actions. Basic features of the theory of using information for system action have also been listed, and the concept of using information actions is suggested to overcome the described gap. Candidates for building the mathematical theory of using information in system actions have been suggested. Such theory should allow using big data about events and processes (e.g. in log files) and alternations to processes and big data about the realisation of information operations. Such data can be used to build models of alternated processes, models of possible alternatives and models of information operations, all of which should estimate the quality of the results of system actions regarding information actions used and be able to synthesise optimal characteristics of such actions based on big data available. New types of applications can be created based on models of the results of system actions, alternated in light of the use of information actions—among them, applications for the learning of system information actions for the best results of system actions in volatile environments and applications to predict system response to information operations outside the system.

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