Information technologies usage models during agile systems functioning

A S Geyda, I V Lysenko
St.-Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences, 14 line, 39, St.-Petersburg, Russia

Abstract. The article outlines conceptual and derivative formal models that provide means for estimation of operational properties of agile systems operation with regard to the use of information technologies. The estimation is fulfilled analytically through plotting the dependences of predicted values of operational properties against variables and options of solved tasks. To develop this type of models, the use of information technologies during agile systems functioning is analyzed through a technological agile system. General concepts and principles of modeling of information technology use during operation of agile systems are defined. An exemplary modeling of effects of technological informative and related technological non-informative operations of technological agile systems operation is provided. Based on conceptual models of operation of agile systems with regard to information technologies use, set-theoretical models followed by functional models of agile systems operation using information technologies are introduced. The examples of calculated factors of agile system operational properties and information technologies use are given. The obtained results allow to evaluate predicted values of agile systems operational properties and information technologies use; they help to analytically estimate the efficiency of implementation of new information technologies depending on variables and options in solved tasks.

1. Introduction
The article introduces conceptual and formal models of agile systems functioning with regard to the use of information technologies (hereinafter referred to as “IT”). Their first distinctive feature consists in their revealing of relations between environment impact (that may lead to imperative improvement of the system and its operation) and informative and non-informative actions required for this system operation as a reaction to impact of the environment. Second, the developed conceptual models facilitate transition from geometric graph and set-theoretical to functional models that describe the connections revealed at conceptual modeling using analytic dependences between: Agile system operational properties (from here referred to as “OP”) with regard to IT application, impact of system environment, and informative and non-informative effects of agile system functioning.

These models are required to solve research tasks as mathematical problems of operations research and mathematical programming. To develop such models analytic relations between informative and non-informative effects and impact of the environment are revealed in such a way that: First, the models would be based on patterns of operation conditioned by changing environment. Second, the models would register potential demand to implement processes of improvement of systems and their operation (as a reaction to changing environment). Third, they would register subsequent transient behavior of changes in the system and its functioning.
Following these models and given the use of IT, analytic dependences of OP predicted values in an agile system are plotted against variables and options in solved research tasks, namely, in estimation problems, during evaluation of agile systems OP with IT use, in design problems of agile system functioning (with the account of transition processes in operation) on the basis of OP factors of agile system functioning at IT use. To describe the relations between informative and non-informative effects at agile systems functioning (hereinafter referred to as ASF), concepts and principles (conceptual model) of IT application during ASF are suggested. By applying these concepts and principles, general patterns of IT application effects in the context of ASF are revealed. The suggested conceptual model provided for transition first to graph-theoretical, set-theoretical and then to functional model of IT use in the context of ASF that is based on patterns of non-informative effects development with the use of informative effects. Based upon practical application, solution of these problems is relevant when researching: Enterprise architectures, use of IT, implementation of governmental projects and programs involving the use of IT. Research is now becoming ever more relevant due to the fact that analytical research of agile systems OP with regard to IT use supports scientifically based improvements of parameters of informative actions, their relations with other actions depending on changing requirements of the environment and with the account of ASF specifics.

2. Information technologies use during agile systems functioning: general concepts and principles
IT application in the context of ASF is exemplified with IT application in technological agile systems (hereinafter referred to as “TAS”) (including the related transition processes and IT application). Suppose, their operation is technological if defined by execution of technological operations, specifically by definition of technological operation execution in technological documentation in TAS. These include, for instance, systems that function to enforce manufacturing of unique products (e.g. in aerospace industry) and systems for implementation of governmental projects and targeted programs. General concepts required for development of models of IT application in the context of TAS include: IT, IT application, information, information use, system, system operation, purposeful changes in system operation, target, outline of changes in system operation, benefit, technological informative operation, technological non-informative operation, system operation effects, effects of transition processes during functioning. Concepts are linked together in a complex on a scheme of purposeful changes to ASF with the application of IT (figure 1). IT effects [1] are manifested at ASF conditioned by changes in operation (for example, by transition processes from reaching one target to reaching another). This change in operation becomes apparent in changes in non-informative actions (their composition, properties and sequence). The changes in non-informative actions are caused by results of the informative actions. Implementation of informative actions is governed by necessary consideration of environment impact at ASF. As a result of the series of changes, the personnel using TAS acquire the effects different from those that would appear, should there have been no changes, that is, not considering environment impact or the new ASF, conditioned by this impact. The operation implementation with new chosen parameters is explained by technological informative operations implemented to consider environment impact. These technological informative operations provide for selection of next technological operations with better parameters (in effected conditions) depending on the changes in the states of TAS and its environment. Best operational effects are achieved through consideration of these changes at execution of technological information operations. The use of different types of technological operations (from now on referred to as “TIOp”), e.g. informative, non-informative, at ASF depending on verified TAS states and its environment is illustrated on figure 1.
When TIOp sequences are implemented, first technological informative operations (hereinafter referred to as “TIO”) are executed. These operations estimate changed states of the environment and system elements with regard to environment impact. Further, TIO liable for changed TIOp are executed (if necessary). Their target result is to obtain information about the TAS state and its environment and what should be changed with this regard. Then technological non-informative operations (hereinafter referred to as “TNIO”) connected with informative operations by cause-effect relations are executed through practical implementation. The notions of information and IT, benefits of IT, benefits of information, informative and non-informative actions, TIOp, TIO, TNIO and other related notions were specified in [1]. Principles of agile system research and a number of related notions were introduced in [2]. General OP characteristics were defined in [3]. Let us specify the notions that are used further in the context of functional modeling of ASF.

Technological informative operation (TIO) is an informative action to be taken according to the technological documentation (e.g. manuals, descriptions). Technological non-informative operation (TNIO) is a non-informative action to be taken according to the technological documentation. Technological informative operations are executed according to a certain information technology. TIO (or, as a rule, a number of TIO) aims at obtaining (creation) and transforming the information into such a form, where it could be used by a person or technical equipment to solve a task of choosing (for instance, choosing a mode of TNIO).

During implementation of TIO and TNIO sequences, depending on the occurred events and states of TAS elements and environment, which were revealed as a result, different TIO are executed. Then TIO are used for choosing various TNIO resulting in occurrence of various events and states of TAS. In this regard, the states of TAS and environment do not recur during operation in reality, and sequences of TIOp, events and states (a loop in figure 1) should be expanded into structured sequences of events and states (outcome tree). As a result, numerous possible state sequences are obtained. They are connected by branches (events) depending on states of TAS, environment and implemented sequences of TIOp (TIO and TNIO), and the events, which are revealed during TIOp execution. TAS operation outcome is a sequence of conditioned states of TAS and branches (events) between them caused by TIOp (TIO and TNIO) and actions of TAS environment. During operation, the actual TAS operation outcome is reviewed, being a sequence of implemented TAS states and branches between them caused by TIOp. During planning, the possible operation outcomes are reviewed, being a sequence of possible states and branches between them caused by TIOp (TIO and TNIO). Composition and characteristics of TIOp, which lead to possible operation outcomes, change.
as a result of TIO. TIO lead to various sequences of random events and states revealed as a result of changes in environment states. These events and states form possible outcomes. Each possible outcome, except for various possibility measures of its implementation (depending on states of TAS and environment, and implemented TIop) complies with different effects (results with specified requirements) of operation and different operation efficiency. Operational properties of TAS and IT, namely TAS potential OP (with regard to IT application), describe system parameters associated with its operational efficiency in changing conditions. This property should be estimated based on the modeling of all possible operation outcomes. TAS potential is a property that indicates if an agile system is suitable to reach changing targets (actual and possible). It would be rational to use the difference between TAS with applied “new” and “old” IT as an indicator of operational properties of the “new” IT compared with previously use one. This indicator should be estimated on the basis of analytic models developed through description of laws and manifestation patterns of effects, as a result of execution of TIO and TNIO sequences of various characteristics at different TAS operation outcomes.

3. Modeling of information technologies use: general concepts and principles

Concepts applied during development of ASF models with regard to transition actions of TAS improvement, and principles applied during conceptual and formal modeling of agile systems were defined in [2]. Let us consider general concepts, which require interpretation due to suggested concept of IT application in the context of ASF. Simplex of TIoP (simplex) is a sequence of initial TIO (TIO required to initiate TNIO), TNIO and final TIO (TIO required to terminate TNIO). Reduced simplex (hereinafter referred to as “RS”) is a simplex containing zero TNIO. There are several types of RS depending on the type of state evaluation task they solve: If RS solves a task of general TAS state evaluation at the moment (to the moment) then it is type one RS. If RS solves a problem of state evaluation of several sites at the moment (to the moment) then it is type two RS. Depending on their specifics, different RS should be executed to evaluate the states of TAS and environment as a result of execution of simplexes.

This rule is fixed by a principle of simplex linking through RS implementation. These RS are implemented differently depending on the results of execution of prior TIop and environment states. RS target result consists in chosen composition and course of further actions. This result should be used in consequent non-reduced simplexes to achieve target results of TNIO (e.g. treated blanks). While different sequences of simplexes and RS should be executed differently (depending on various recorded states of TAS and environment), different states are implemented as a result. Afterwards these states could lead to implementation of various simplexes and TAS transition into next states, as a result.

Definition of these sequences is given as a principle of functional dependency of TAS operation outcome from simplexes and states of TAS and its environment.

Nodes of an outcome tree are possible states achieved as a result of TIop (TIO and TNIO by selected means), and tree edges stemming from the parent node are possible outcomes (transitions between states) resulting in TIop implementation. Tree branching line at TAS operation complies with one of the (possible) functional events providing it became actual. If a TAS state during operation is calculated on the basis of the state of several sites and respective RS of type two, the subtrees complying with possible states of sites and their combinations are connected into the branch. The outcome tree corresponds with all possible TAS operation outcomes. Composition and characteristics of outcomes and the outcome tree depend on the TIop composition and characteristics, and, as a result, on the used IT. In particular, possibility measure of implementation of every possible outcome (possibility measure of reality of outcome) depends on the composition and characteristics of TIop (TIO and TNIO) and state of environment at operation. Operation effects achieved as a consequence of certain outcome implementation depend on the composition and characteristics of TIop (and the IT) and on the states of environment at operation. Knowing the possible outcome and characteristics of the effects, providing this outcome is real, one could calculate TAS potential.
4. An example of functional models of use of information technologies during agile systems functioning

The functional models are developed through systematic re-expression of geometric graph and set-theoretical models. Let us set:

\[ m_{b,d} - d \rightarrow \text{event method } a_{b}, \text{ of a set } M_{b} = \{m_{b,d}; d = I, D\}, \text{ of methods (described as possible implementations and predicted outcomes of events in technological documentation);} \]

\[ C_{i} - i = \text{TAS operation outcome, possible sequence of outcomes of events (outcome tree branch);} \]

\[ e_{i,k}(m_{b,d}) = \langle s_{i,k}, s_{i,k+1}(m_{b,d}) \rangle \rightarrow \text{event consisting in transition of elements to sites involved in the event } a_{b} \text{ from state } s_{i,k} \text{ to state } s_{i,k+1} \text{ as a result of event execution } a_{b} \text{ through } m_{b,d} \text{ (i.e. event outcome } a_{b} \text{ at site by } m_{b,d} \text{ - method);} \]

\[ C_{i} = \langle s_{i,0}, e_{i,0}(m_{0,i}) \rangle, \ldots, (s_{i,k}, e_{i,k}(m_{k,i})), \ldots, (s_{i,K}, e_{i,K}(m_{K,i})) \rangle ; \]

\[ s_{i,k+1}(m_{b,f}) = \langle \tilde{y}_{i,k+1}(m_{b,f}) \rangle \rightarrow k + 1 = \text{state being terminal in event outcome } a_{f} \text{ by } m_{b,f} \text{- method initiated from } s_{i,k} \text{, functional event element } C_{i}. \text{ It is represented as a vector of effects as a result of } k \rightarrow \text{outcome of } e_{i,k}(m_{b,f}) \text{ event } a_{f} \text{ in operation } C_{i} \text{ outcome;} \]

\[ \{m_{0,i}, \ldots, m_{k,f}, \ldots, m_{n,i}\} \rightarrow \text{event methods } a_{b}, \ldots, a_{f}, \ldots, a_{n} \text{ revealing an outcome of event set of TAS functioning } C_{i} \text{ (i.e. outcomes of events } a_{b}, \ldots, a_{f}, \ldots, a_{n} \text{ if implemented in such a way that the respective outcomes are included in outcome } C_{j}); \]

\[ s_{i,K} = \langle \tilde{y}_{i}(C_{i}, t_{k}) \rangle \rightarrow \text{state at outcome end of TAS functioning event set } C_{j}, \text{ namely, vector of effects } \tilde{y}_{i}(t_{k}) \text{ of functioning, fulfilled to the moment } t_{k} \text{ of operation end according to event set outcome } C_{j}, \text{ where } k \rightarrow \text{is a number of the terminal event outcome in } C_{i} \text{ (i.e. number of end TIO outcome in } C_{j}); \]

\[ a_{b} \text{ may be specified by event associated with it } e_{i,k} \text{ at implementation } a_{b} \text{ by methods } m_{b,d}: \]

\[ a_{b} = \{e_{i,k}; m_{b,d} \} \text{. } T_{e}(C_{a,d}^{h}) = \{C_{a,i} = I, I\} \text{ - } c \rightarrow \text{tree of possible outcomes of TAS functioning constructed for a preset sequence } C_{a,d} \text{ of directive states formed at the boundary of TAS and its environment (environment operation outcome at TAS boundary) and for a preset } IT \text{ } h \text{ from a set } H \text{ of possible } IT. \]

Outcome } C_{a,d} \text{ of environment operation at TAS boundary is set by possible environment impact on TIOp elements at ASF. The outcome in the example is characterized by set, constant effects required only for } C_{i} \text{ termination.} \]

Required informative and non-informative effects [2] are understood to be primary results of an action, both target and providing (resources, time). The tree is constructed at the stage of planning depending on the following: outcomes of environment operation } C_{a,d} \text{ (of which there are several, in general), possible TIO set in relation to the applied } h \rightarrow \text{IT and boundary states; relations between TIO and TNIO depending on the used technology; TAS changing states as a result of environment impact.} \]

\[ p_{i,k} = \text{Poss}(E_{i,k}) \text{, where } \text{Poss}(E_{i,k}) \rightarrow \text{is a possibility measure of a random event } E_{i,k}; \]

The possibility measure has a broad definition here [4] as one the measures (probability, indistinct measure, other types of measures and their combinations).

\[ E_{i,k} \rightarrow \text{a random event that involves that the } k \rightarrow \text{outcome (transition } e_{i,k} \text{ between states) at event implementation } a_{b} \text{ is accomplished accordingly.} \]

As a result of each environment operation outcome } C_{a,d} \text{ at TAS boundary and each TAS operation outcome } C_{i} \text{ with application of one IT or the other, a different alignment is formed (at boundary of TAS and its environment). This alignment should be checked for the best choice of IT. Assume:} \]

\[ \tilde{y}_{j,i} \rightarrow \text{value } j \rightarrow \text{of operation effect to the end of } C_{i}; \tilde{y}_{j,i} = f(C_{i}). \text{ For instance, labor content of service, power costs.} \]

\[ \tilde{y}_{j,i}^{a} \rightarrow \text{requirements from the environment to } j \rightarrow \text{operation effect to the end of } C_{i}; \tilde{y}_{j,i}^{a} = g(C_{i}, C_{a,d}). \]
\[ p_i(C_i, C^0_u) = \prod_{\xi : \xi \in \mathcal{C}_i} p_i(C_i) \] – possibility measure of implementation of TAS functioning outcome \( C_i \) providing the outcome at boundary between environment and TAS is \( C^0_u \); Then:

\[ W_j(C_i, C^0_u) = \prod_{\eta, \xi : \eta \in \mathcal{C}_j} \text{Poss}(\mathcal{Y}_j(C_i \eta, \mathcal{Y}_j(C_i, C^0_u))) \] – possibility measure of meeting the requirements at TAS functioning outcome \( C_i \) and environment operation outcome \( C^0_u \) (TAS performance measurement at preset outcomes of TAS and its environment operation). Results of TIOp package should be estimated with the account of all possible functional events at different environment impact and during different TIOp (TIO implemented according to preset IT and TNIO, which are carried out with regard to preset non-informative technology). Scalar characteristic of TAS potential meets this requirement, potential function [2] when \( h \) IT is applied, calculated across all environment operation outcomes \( C^0_u \), with regard to possibility measures \( p_u \) of their implementation:

\[ \psi(T, h) = \sum_{C^0_u} \left[ \sum_{C^0_c \in \mathcal{C}_u} W_i(C_i, C^0_u) \cdot p_i(C_i, C^0_u) \right] \cdot p_u \cdot (h). \]

Assume there are two IT, \( h \) (“new”) and \( f \) (“old”). For them \( e \) – (for \( h \) – IT) and \( p \) – (for \( f \) – IT) trees of outcome for TAS operation were constructed \( T_{e u}(h) \) and \( T_{p u}(f) \) for every possible outcome \( C^0_u \) of environment operation at boundary with TAS from the tree of environment operation outcome \( T_e \) (at fixed outcome \( C^0_u \) TAS functioning outcomes form trees \( T_{e u}(h) \), \( T_{p u}(f) \) of TAS operation outcomes when \( h \) – and \( f \) – IT are applied). Let us define the difference between TAS potential function values when old and new IT are applied. \( \Delta \psi(h, f, T_e) = \psi(T_e, h) - \psi(T_e, f) \).

This difference defines OP of the “new” IT application as compared to the “old” one given the execution of the same outcomes \( C^0_u \) of environment operation at the TAS boundary with the same measures of possibility \( p_u \), according to the preset \( T_e \). The difference defines the target effect of new IT application. The target effect reflects how suitable the IT is to reach changing targets (according to the outcomes of environment operation at boundary with TAS). The described target effect is to be compared with effects that ensure the target effect is reached (at IT application). This should be done using efficiency factors of the new IT application.

Efficiency factor of the new IT application could be introduced traditionally [3] as a possibility measure evaluating if the characteristics of the effects meet the requirements. The factor should be estimated in the context of possible outcomes of environment operation \( C^0_u \) at TAS boundary with the account of value of potential \( \psi(T_e, h) \) function for \( h \) IT. If it measures positively meaning the new IT should be implemented then the result should be used as a performance indicator of \( h \) IT as compared with the previously used IT. For further calculation of efficiency factor of \( h \) IT implementation, the agility of \( h \) IT implementation and resource intensity of \( h \) IT implementation should be evaluated as well.

5. References
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