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FORMALIZATION OF IMPLICIT PROCEDURE-ORIENTED DEPENDENCES IN KNOWLEDGE-INTENSIVE BUSINESS-PROCESSES

Analysis of the peculiarities of the implicit procedure-oriented dependences of knowledge-intensive business processes (KBP) is carried out. Such dependences are shown to determine limitation regarding the selection of process actions and additional conditions for realization of non-typical actions sequences. The model of implicit procedure-oriented dependences of knowledge-intensive business-process, containing the rules of process action selection in one of the following states of the process, taking into account the conditions of current state of business process context and the limitations on process actions realization is suggested. The approach to the formalization of the implicit procedure-oriented knowledge of knowledge-intensive business process, based on the analysis of its log is proposed. The approach provides stage-by-stage complement of the explicit rules of actions selection of formalization process by implicit procedure-oriented dependences.

Key words: *knowledge-intensive business-process, process mining, process-based management.*

Introduction

Business processes (BP) are main components of process-based management [1]. By definition, the business process is the sequence of «various types of the activity, within which, “at the input” one or more types of resources is used and as a result of such activity «at the output», the product, valuable for consumer is created» [2]. Process of enterprise management provides the construction of business-processes (BP) models and further management of the processes, using these models. Within the frame of process management constant improvement of business-processes models takes place. By means of process mining methods «as it is» models of the processes, that have already been carried out are formed. Further, the comparison of apriori BP model in process information system and «as it is» model, obtained by means of process mining is realized. By the results of such comparison business-process model is improved. In the process of improvement changed action sequences, corresponding to the context of BP realization are included.

Model «as it is» of business process, being realized, is created by means of the process mining on the base of analysis of such processes logs [3, 4].

Log contains records, regarding the course of BP realization in the form of events sequence. Model «as it is», as rule, has the form of workflow – graph, that represents the algorithm of BP operation. Such models are analyzed by analysts in order to reveal “bottlenecks”. By the results of the analysis BP model is improved.

However, for such kind of business –processes , as knowledge-intensive BP (5) conventional methods means of process-mining form spaghetti-model, that has minor practical value (6, 7).

Graphs of such processes resemble the dish of spaghetti: they consist of a great number of peaks and arcs between them, that reflect all possible variants of BP realization, irrespective of the frequency of their emerging in practice.

The sources of the considered spaghetti problem are in structural peculiarities of knowledge – intensive business – processes. Knowledge–intensive business-processes (KBP) have several definitions. However, all the definitions point only to

the usage of the executors knowledge in the course of the process: it is “business - process that creates values only on condition of satisfying of the requirements to the level of knowledge of process participants “[5], it is the process “whose execution greatly depends on the executors, as knowledge carriers” [8]. That is why, in the process of KBP construction, it is necessary to take into account knowledge, determining the sequence of process actions in the current context [9]. Such processes do not contain apriori set algorithm of process execution for all possible context states. The change of the actions sequence, set in apriori model, is realized by the executors of business – processes, using both formal, explicit and their personal procedure – oriented knowledge.

Thus, the problem of structuralization and modeling of the implicit procedure – oriented knowledge, that determine the sequence of process actions in the given context is really actual.

Analysis of the research and publications

The problem of structuralization and formalization of knowledge is one of the most important problems of knowledge management. Knowledge is the reflection of the individual or group of individuals notions regarding the phenomena and regularities of the world. Knowledge consists of the set of statements, reflecting properties of the objects, regularities of the process and phenomena as well as logic connections between these statements that could be used for decision making [10, 11].

In knowledge – intensive business processes organization knowledge, i.e., knowledge of the organization, where business – process is performed, is used. Organization knowledge, as a rule has two forms: explicit and implicit [12, 13].

Knowledge in the explicit form, as a rule is presented in the form of documents, formulas, business – rules. Implicit knowledge reflects experience, skills, intuition of the human being. Implicit knowledge is difficult to verbalize, and as a rule, it is transferred by people in the course of direct contact. The process of knowledge transformation from implicit into explicit form is called externalization [12]. In [12 - 16] general properties of implicit knowledge and impact the knowledge on human interaction are shown. In particular, in [16] the impact of implicit knowledge on the sequence of practical problems solution by human being is analyzed. In general, main attention in these papers is paid to structuralization of human interaction. At the same time in the course of processor control such implicit interaction is not shown in BP models, that is why, it influences the efficiency of these processes control. Thus, the problem of formalization of implicit procedure dependences, that determine the sequence of knowledge – intensive business – processes in the specific context, require further consideration.

Problem set-up

Transformation of the implicit procedure knowledge into explicit form is based on the usage of business – process context in the course of execution of its actions

sequence. The context of the process is considered as the environment or medium of business-processes, influencing their realization.

For the usage of implicit knowledge in business – processes control systems it is necessary to structure the context, allocating its explicit and implicit components as well as formalize implicit component, determining the connection between the state of the context and sequences of process actions.

The aim of the paper – is the development of the model of implicit procedure dependences between the components of knowledge – intensive business – process, that enables to formalize possible and admissible actions in accordance with the context state.

In practical aspect, the model of procedure implicit dependences enables to allocate the fragments of KBP model, that were executed as a result of application of such knowledge and, make workflow of the model of knowledge- intensive processes, suitable for analysis and application.

The object of the given research is knowledge – intensive business process. Knowledge – intensive business-process (KBP) differs from conventional business – processes with apriori set structure by the fact that the sequence of its realization could be changed by the skilled workers during its realization. Such process consists of three levels: level of the context, level of knowledge, level of workflow.

Under the context level of BP we will assume the set of objects, used in the process of its actions execution. For instance, the context of business – process comprises all the resource objects (materials, equipment, etc.) needed for execution of its actions [17].

Work flow – it is an abstraction of actions sequence, performed in the course of practical problem solution by a person or by a group of people, mechanism, etc. That is why, workflow level of business – processes description contains actions algorithm, that enables to obtain the result of business – process.

The selection of a specific actions sequence, depending on the context, is determined by means of procedure knowledge. Implicit component of procedure knowledge sets such rules of actions selection, which are known only to the executors. These rules are not included in apriori model of business – process. After the externalization (conversion into explicit form) of such knowledge, it can be included into process model).

To achieve the aim of the research the following problems are solved:

- structuralization of the implicit procedure knowledge in general;
- development of the model of implicit procedure dependences of knowledge – intensive business -process;
- development of the approach to formalization of the implicit procedure knowledge.

Model of the implicit procedure dependences

Implicit procedure knowledge is the component of the procedures of applied knowledge solution, presented in the form of the set of admissible actions sequences

and taking into consideration non –formalized limitations in the given subject area. The given type of knowledge corresponds to the skills in natural intelligence [14].

In practice, such knowledge is used for the selection of both separate actions, aimed at solution of practical problems and sequences of such actions in the preset context. It should be noted, that the context in the given case may be formalized only partially.

Relational implicit knowledge, regarding the state of the context, determines the connection between the properties of its objects and rules of the context objects usage.

Determination of implicit procedure knowledge is an important condition of formalization of numerous applied problems of process control. For instance, the difference in the efficiency of the same business – processes, realized in separate divisions of transnational corporation in different countries, depends on the implicit procedure knowledge.

Differences in usage of personal knowledge result in the fact that in identical business – processes duration of executor waiting by the clients will differ.

The realized analysis of procedure implicit knowledge enables to distinguish such their peculiarities:

- the set of admissible actions, used in the process of applied tasks solution, as a rule is set in explicit (sometimes in formal) form;
- input information, regarding the context of actions realization could be set both in explicit and implicit form;
- the choice of corresponding actions in the specific context is realized on the base of nonformalized procedure dependences;
- output information, that is the result of the choice and execution of the actions aimed at the solution of the applied tasks, could be presented both in explicit and implicit form.

Context of the realization of actions, aimed at solution of the applied tasks could influence the choice of possible sequences of actions in two different ways.

First, non-formalized interactions between the objects of the context can impose the additional limitations on realization of the actions in specific conditions of subject area.

The designation of such limitations could be different:

- limitations of typical but not sufficiently efficient sequences of actions;
- limitations (or elimination) of such sequences of actions, that hamper the work of executor

Let us consider the example of such limitations. The executor – beginner uses generally – accepted and not always efficient ways of problems solution, whereas the expert will solve the problems in the situation , comfortable for him.

Secondly, such dependences between the context and actions could create the conditions for construction of more efficient procedures of the existing problems solution. The given procedures could not be obtained of the basis of only explicit

knowledge realization, as the latter do not characterize completely the subject area.

New approaches to realization of practical tasks are determined by previously hidden properties of the entities of subject area. It means that from externalized knowledge about the set of entity properties and basic knowledge about the subject area the procedures of such entities usage could be obtained.

The given structuralization enables to determine two kinds of implicit procedure knowledge:

- implicit limitations on admissible in current state of subject area sequence of actions;
- implicit conditions of actions realization, presented in the form of hidden relations between entities of subject area.

Implicit limitations additionally allocate numerous admissible actions in the preset context.

Implicit conditions set sequences of actions, aimed at solution of practical problems . which are alternative typical sequences

As it was mentioned above, KBP consists of the context Ct , knowledge Kn and work sequence Wf (workflow): $BP = (Ct, Kn, Wf)$.

Knowledge level of such business process consists of the following dependences:

- relational dependences between the objects of the context R_{Rl} ;
- procedure dependences between the objects of the context and process actions R_{Pc} ;
- communication dependences between the actions of different business-processes or different specimen of the same process R_{Cm} .

For correct functioning of such business – process it is necessary, that it comprises all the types of dependences:

$$Kn = R_{Rl} \wedge R_{Pc} \wedge R_{Cm} . \quad (1)$$

Each of knowledge level KBP components consists of explicit and implicit components, in particular, for process dependences:

$$R_{Pc} = R_{Pc}^{Tacit} \wedge R_{Pc}^{Ext} , \quad (2)$$

where R_{Pc}^{Tacit} – implicit component of KBP procedure dependences; R_{Pc}^{Ext} – explicit component of procedure dependences.

The realized structuralization shows, that procedure dependences R_{Pc}^{Tacit} contain rules of actions selection depending on the context and limitation on such actions:

$$R_{Pc}^{Tacit} = \bigvee_k r_k^{wf} \mid \bigwedge_m r_m^{lim} , \quad (3)$$

where r_k^{wf} – k -th rule of process action launch, depending on the state of the context; r_m^{lim} – m -limitation on process action realization, depending on the state of its context
Let us consider in details the given rules. In accordance with the approach, being consider, the context Ct consists of the set of objects Af , and relational implicit

dependences $R_{Rl} : Ct = (Af, R_{Ct})$.

:

In its turn, each object of the context characterizes the set of attributes and values of these attributes:

$$af = \{a_i, v_{ij} \mid v_{ij} \in V_i\}, af \in Af, \quad (4)$$

where af – object of KBP context; a_i – i -th attribute of the object; v_{ij} – current value of the attribute a_i ; V_i – set of possible values of a_i attribute.

Each rule of actions selection is determined by means of atomic statements over the attributes of process objects, if they are true, the corresponding action is carried out:

$$r_k^{wf} = \bigvee_l p_l F^+ wf_s, \quad (5)$$

where p_l – atomic statement over the attributes of the object; wf_s – logic description of s – action of the process; F^+ – operator of model logic, that determines the truth of the formula wf_s in the current or one of the following states of the process.

Each limitation is also determined by means of statements over the attributes of the process, however truth of the limitation is set, starting from the current state of the process:

$$r_m^{lim} = \bigvee_l p_l U^+ wf_s, \quad (6)$$

where p_l – atomic statement over the attributes of the object, that determines the condition of the limitation; wf_s – logic description of s – action of the process; U^+ – operator of model logic, that determines the truth of the condition p_l until wf_s is not realized.

On the base of the realized structuralization and formalization of the implicit procedure dependences of knowledge-intensive process the generalized approach to its externalization is proposed. The given approach uses the scheme of skills obtaining in natural intelligence, suggested in [14].

Such scheme provides gradual replacement of implicit knowledge by explicit knowledge by means of their externalization in the process of transfer from carrier to carrier.

The suggested approach to formalization of implicit procedure knowledge is based on the usage of the set of process selection actions and limitations on actions choice in the set context. The set of such rules is constantly replenished by means of formalization of implicit dependences between objects of business – process context.

Knowledge externalization is carried out by means of the analysis of information, concerning business – processes, realized using implicit procedure dependences. The information, regarding BP realization is recorded in logs. Log consists of traces. Each trace represents the realization of one copy of the process in the form of events sequence. Each event represents the state of process action (realization, completion,

expectation, etc.) at discrete moment of time. The event is characterized by the set of the objects, that were used in the process of corresponding action realization. Recording of the events in log's trace, with the account of the attributes of context objects represents the results of implicit knowledge usage during process realization correction by the executors. The description of log's events, illustrating the possibility of revealing implicit dependences is shown in Fig. 1.

It is seen from the given example, that the log event sets on 3:56 28, January 2011 sets the values of attributes of such objects:

- "organization involved";
- "concept:name";
- "product";
- "lifecycle:transition".

```
<event>
<string key="organization involved"
value="Org line V7n"/>
<string key="concept:name"
value="Accepted"/>
<string key="product" value="PROD706"/>
<string key="lifecycle:transition"
value="In Progress"/>
<date key="time:timestamp"
value="2011-02-28T13:46:38+01:00"/>
</event>
```

Fig. 1. Example of log event description

That is, the action of the process "Accepted" in the given case is directly connected with the organization and product. Limitation (6) for the given event has the following form :

$$\text{Organization_involved} = \text{"Org line V7n"} \wedge \text{product} = \text{"PROD706"} \cup \\ \text{concept_name} = \text{"Queued"} \wedge \text{lifecycle_transition} = \text{"Awaiting Assignment"}.$$

In accordance with the given limitation operation of task location in the waiting queue for the executor could be performed for the product "PROD706" in organization "Org line V7n".

Illustrated event, presented in Fig. 1 has small number of attributes. As a rule, events in logs are characterized by a great number of variables. However, even the given example shows that the log of the process contains the links between the objects of the context and events of the process. Such links are the result of the action choice during process execution. This stipulates the possibility of revealing implicit procedure knowledge on the base of logs analysis.

For externalization of implicit procedure dependences methods of intelligent analysis of the processes could be used, as they define the interconnection between events in time. However, the initial logs for intelligent analysis require preliminary filtration of the events on the base of objects attributes, connected with the events of the log. The suggested approach to formalization of the implicit procedure knowledge comprises the following stages (Fig. 2).

Stage 1. Selection of explicit rules of process actions selection in accordance with

the state of the context. Such formalized rules set admissible sequences of actions in the process of problems solution, business – process is intended for. At the given stage knowledge, necessary for problems solution in a typical way in most widely spread situations are determined. For selection (revealing) of the rules traditional methods of knowledge engineering are used.

On the level of organization on the whole, such dependences have the form of business rules. Business – rule (BR) is documented demand to business-process in the form of “condition -result” dependence. Business – rules detail industrial standards, managerial policies at the enterprise [18]. Business – rules can determine statements, regarding the invariant peculiarities of enterprise activity - i.e., dependences R_{RI} according to the expressions (1), conditions for actions realization and limitations on business – process actions R_{pc} , as well as communicative rules of R_{cm} . output. The latter interconnect different states of one and the same or several objects, used in activity of the enterprise.

This enables to organize the interaction of various business-processes that use the above-mentioned objects. Form of business – rules presentation depends on the enterprise: from text files to data bases in specialized control systems of BR, for instance, in the environment of business – rules design IBM Industry Models, environment of rules management ILOG, environment of requirements management to systems IBM RationalRequisitePro, etc.

Stage 2. Complement of the rules system, formed at the previous stage, by externalized (i. e. converted into explicit form) relational implicit dependences in accordance with the expression (2). Implicit dependences represent properties of the objects of KBP context, as well as interconnections between the above – mentioned properties. Relational implicit dependences set additional limitations on the application of already known rules, obtained at the first stage.

Explicit and implicit dependences are divided by the form of representation. Explicit dependences – are formalized dependences, presented in symbolic form. As it was mentioned before, such dependences, as a rule, reflect peculiarities of organization activity and are presented in the form of business-rules. Implicit dependences can not be directly presented in the form of symbols, because they represent the practical experience of the executors.

They determine the actions, the executor performs in specific conditions, where business – process is realized, that is why, to reveal such knowledge, its conversion into explicit form, analysis of logs (journals of events registration) of business processes is used.

Detailed description of the structure of business-process log and its separate events is given in explanation note to Fig. 1. Log of business -process usually is contained in text or xml-file.

On the whole, problem of formalization of relational implicit dependences exceed the frames of the given research. However, it should be noted that in such dependences the change of connections in time is not taken into account, that is why,

for their finding it is expedient to use datamining methods.

Each of the events in the input journal is characterized by the values of context objects attributes, used by business process at corresponding moment of time, as it is shown in Fig. 2.

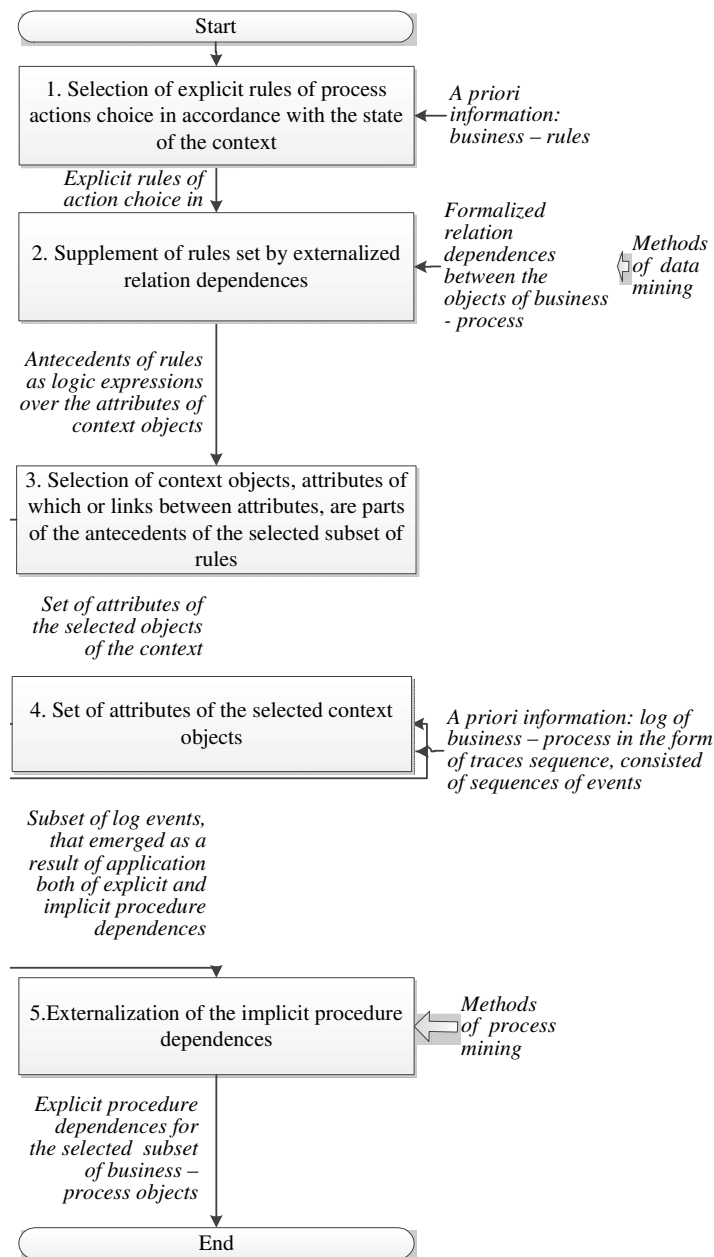


Fig. 2. Stages of the approach externalization of the implicit dependences

Connections between the objects could be obtained by means of the known algorithms of associative rules search, for instance, APRIORI. As a result of this stage execution additional connections between the objects of the context, which are absent in the set of business – rules of the enterprise are revealed.

After verification of the obtained dependences by business – analyst it is expedient to consider them as business – statement on invariant peculiarities of enterprise activity and that is why, they could be added to corresponding set of rules.

Stage 3. Determination of the subset of context objects, attributes of which use the

rules of process actions selection. In other words, from the attributes of the events, the example of which is shown in Fig. 2, it is necessary to pass to objects attributes (4). It should be noted, that each event contains the attributes of various objects.

The example is given in explanation to Fig. 2. Such objects will be added to the resulting subset. It enables to form the antecedent of the revealed rules from the attributes of the selected objects of the context.

Implicit procedure knowledge includes the conditions of actions realization, that could be true only at certain moments of time – i.e., such knowledge has temporal component and that is why, the set of context objects is formed both by temporal and object signs.

Stage 4. Filtration of the log: the selection of the events subset with the attributes, that correspond to the selected attributes of context objects. From the example of events description, given in Fig. 1, it is seen, that each event contains the value of attributes for final, as a rule, limited, number of context objects. That is why, the selection of attributes is a trivial problem from the practical point of view.

Stage 5. Determination (i.e., conversion in the explicit form) of the implicit procedure dependences (5), (6), by means of process mining. The subset of input log events performs the role of input data, this subset was filtrated according specific attributes at the stage 4.

As the actions of the process are presented by their attributes in log events description (Fig. 1), then for the search of procedure dependences on the base of analysis of events attributes as at the stage 2, it is expedient to apply data mining methods.

The suggested approach to the construction of procedure knowledge representation by means of uniting of explicit and implicit components is directed to determination of dependences, enabling to solve efficiently practical problem as well as rules that substantiate the efficiency of such actions sequence in the specific situations.

Further development of the approach is connected with the organization of logic conclusions on explicit and formalized implicit procedure knowledge in order to determine the efficient, depending on the context KBP (knowledge –intensive business-processes) action sequences.

Conclusions

The analysis of the peculiarities of implicit procedure dependences of KBP is performed. It is shown that such dependences determine restrictions on the choice of process actions and additional conditions for execution of non-typical sequences of actions in order to solve functional problem, for solution of which knowledge-intensive business process is designated.

The model of implicit procedure dependences of knowledge – intensive business process is suggested, the given model contains rules of process action choice in one of the following states of the process, with the account of the conditions of business-

process context current stage as well as restrictions on process actions realization. The approach to formalization of the implicit procedure dependences of knowledge-intensive business-process on the base of its log analysis is suggested. The approach provides step-by-step addition of explicit rules of actions selection of the process with formalized implicit procedure dependences. The obtained model and approach serve as theoretical base for the construction of context-dependent presentation of the implicit knowledge. Such representation enables to realize externalization of implicit dependences of business-process by means of analysis of the attributes of its logs events.

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